Thesis/
Reports
Kaluarachchi,
J. J.

FINAL REPORT FOR RESEARCH AGREEMENT
#INT-95129-RJVA
"Water Quantity and Quality Analysis of
Mining Areas Located Within Wasatch Plateau
of Central Utah"
UTAH STATE OF UNIVERSITY
FS Contact: Dr. Ray W. Brown
CoOp Contact: Dr. Jagath J. Kaluarachchi

Assessment of Water Quantity and Quality in Mining Areas of Manti-La Sal National Forest: Cottonwood and Huntington Watersheds

Document Part III: Extension of Assessment to Price River Watershed

---

Project Report Submitted to the
Rocky Mountain Research Station
USDA Forest Service
Logan, Utah

by

Jagath J. Kaluarachchi[1] and Mamun Rashid[2]
Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, UT 84322-8200

Cooperative Project Agreement Number: INT-95129-RJVA
Project Officer: Dr. Ray Brown

February 1999

This research was supported in part
by funds provided by the
Rocky Mountain Research Station,
Forest Service
U. S. Department of Agriculture

Property of
National FS Library
USDA Forest Service
240 W Prospect Rd
Fort Collins CO 80526

[1]Associate Professor, Civil and Environmental Engineering
[2]Graduate Student

Property of
National FS Library
USDA Forest Service
240 W Prospect Rd
Fort Collins CO 80526

TABLE OF CONTENTS

ABSTRACT 3

LIST OF TABLES 7

LIST OF FIGURES 12

1.0 INTRODUCTION 16

2.0 PROJECT OBJECTIVES 19

3.0 PRICE RIVER WATERSHED 21

3.1 Introduction 21
3.2 Hydrogeology 21
3.3 Coal Mining Activities 24
3.3.1 White Oak Mine 24
3.3.2 Skyline Mine 26
3.3.3 Starpoint Mine 30
3.4 Analysis of Water-related Data 37
3.4.1 Types and Sources of Data 37
3.4.2 Selection of Monitoring Stations 38
3.4.3 Statistical Analysis 46

4.0 RESULTS AND DISCUSSION 47

4.1 Precipitation and Evapotranspiration 47
4.2 White Oak and Skyline Mines 49
4.2.1 Background Concentrations 49
4.2.2 Whiskey Canyon 51
4.2.3 South Fork 62
4.2.4 Eccles Creek 69
4.2.5 Finns Canyon 103
4.2.6 Boardinghouse Canyon 106
4.2.7 Mud Creek 114
4.2.8 Burnout Creek 127
4.3 Starpoint Mine 131
4.3.1 Background Concentrations 131
4.3.2 Tie Fork Canyon Area 132
4.3.3 Right Fork Miller Creek Area 144
5.1 Precipitation and Evapotranspiration 167
5.2 White Oak and Skyline Mines 167
5.3 Starpoint Mine 170
5.4 General Remarks 172

6.0 RECOMMENDATIONS 174

7.0 REFERENCES 176

APPENDIX A - Trend and Correlation Tables 178

ABSTRACT

Assessment of Water Quantity and Quality in Mining Areas of Manti-La Sal National Forest: Cottonwood and Huntington Watersheds

Document Part III: Extension of Assessment to Price River Watershed

by

Jagath J. Kaluarachchi and Mamun Rashid
Utah Water Research Laboratory
College of Engineering
Utah State University
Logan, UT 84322-8200

The first two documents of this three-part series discussed the water-related data, analysis, results, conclusions, and recommendations related to historical changes and current status of water in Cottonwood and Huntington Watersheds. This document is Part III of this series aimed at discussing the water-related data in the Price River Watershed.

The three mines studied in this project include White Oak, Skyline, and Starpoint. The water flow and quality data were obtained from the APPX data base of the Utah Department of Natural Resources and data bases of the US Geological Survey. The monitoring stations included streams, springs, mine interceptions, mine discharges, and ground water. Although there are many monitoring stations listed in the APPX and USGS data bases, only a selected number of stations contained sufficient data relevant to the study area. The final analysis included 20 stream, 13 spring, one seep, 4 mine discharge, 4 mine interception, and 5 ground water stations. The different tasks of this study were i) development of conceptual models providing hydrogeological information of mine permitted land; ii) statistical analysis for trend, seasonal mean, and correlation; iii) time-series distributions; iv) data tabulation for identifying chemicals of concern, and minimum and maximum concentrations; and v) data interpretation, conclusions, and recommendations. The major surface water pathways

analyzed include Whiskey Canyon, South Fork, Eccles Creek, Finns Canyon, Boardinghouse Canyon, Mud Creek, Burnout Creek, Tie Fork Canyon, and Right Fork Miller Creek.

The precipitation and evapotranspiration data from the National Weather Service station located close to the Skyline Mine boundary indicated that evapotranspiration exceeded the precipitation by three-fold from 1984 to 1997. However, evapotranspiration was only one-third of the precipitation during the winter months of the same period. The flow in Whiskey Canyon closer to Eccles Creek showed an increasing seasonal trend from 1977 to 1985 followed by a decreasing trend. The water quality of Whiskey Canyon was poor with respect to TSS, TDS, iron, and manganese; and the quality deteriorated towards downstream. The flow in South Fork, which is a tributary to Whiskey Canyon, showed a loss of water from 1978 to 1998 with no serious water quality concerns. The flow in Eccles Creek continued to be high and showed a general trend of increasing flow from 1981 to 1997. The contribution of mine discharges to the flow of Eccles Creek was less than 10% indicating substantial contribution from surface runoff and base flow, probably associated with the O'Connor Fault. The water quality of Eccles Creek was extremely poor; and major concerns were due to TSS, TDS, iron, sulfate, and manganese. Finns Canyon showed a decreasing seasonal trend of flow from 1980 to 1995 from data from a single stream station while indicating no serious water quality concerns. Boardinghouse Canyon showed a decreasing seasonal trend of flow in Mud Creek indicating some concerns related to the flow of Mud Creek. However, the flow of Boardinghouse Canyon remained higher than Finns Canyon from 1980 to 1995. The flow in Mud Creek showed variability between different stream stations, but overall results indicate no real concerns to flow or eventual contribution to Scofield Reservoir. However, the water quality remained a serious concern in Mud Creek with respect to TDS, TSS, iron, sulfate, and manganese. Burnout Creek located east of Electric Lake showed some decreasing trend of flow from 1981 to 1996. Flow data from Wild Cattle Hollow monitored by Starpoint Mine showed poor water quality. The stream data from the North Fork of Miller Creek showed an increasing seasonal trend from 1988 to 1997, but with poor water quality, especially related to TDS, iron, and sulfate.

The springs selected in the analysis generally showed consistent flow except for a few springs that showed high flows during the entire monitoring period and the absence of reliable data. In general, the springs were not affected by sudden drying, and water quality was not a major concern except slightly elevated iron or manganese concentrations. The mine discharge stations located along Eccles Creek had consistent flow from the 1980's to 1996. Two of the mine discharges are to nearby sedimentation ponds, and the other two are UPDES stations discharging directly to Eccles Creek. Two mine discharge stations and one UPDES station located upstream of Eccles Creek had serious water quality concerns with respect to TDS, iron, manganese, and sulfate. The most downstream UPDES discharge station in Eccles Creek did not have serious water quality concerns and maintained flow from 1982 to 1996. The mine interception stations from Starpoint Mine produced water consistently since 1988. The quality of mine intercepted water was poor with high concentrations of TDS, iron, and sulfate. The quality of ground water in the Whiskey Canyon area was satisfactory. However, ground water wells downstream of Mud Creek and Tie Fork Canyon showed poor water quality with respect to TDS, iron, and sulfate.

The correlation results between different parameters of flow or quality produced consistently poor results indicating that there are many other unknown mechanisms controlling the behavior between the parameters of interest.

Overall water flow data did not indicate substantial water losses from streams or springs to affect the downstream water users. However, some streams and springs indicated long-term decreasing seasonal trends of flow. The recharge from base flow through nearby faults and surface runoff during spring may have managed to maintain flow in streams and springs. Some mine interception and mine discharge stations showed poor quality water together with parts of Mud Creek, Eccles Creek, and Whiskey Canyon. There is no strong evidence to indicate that any of the land uses, including coal mining, is responsible for these events. It can be concluded that natural geochemical reactions between water and formation material may be partly responsible for poor quality water in some areas. However, this conclusion does not necessarily indicate that current land uses are acceptable except to indicate that additional data may be needed to evaluate the actual impacts.

The major limitations of this study are that the results from a detailed tracer study were not available for a comprehensive evaluation of hydraulic connectivity between different sources and formations, and data from the Starpoint Mine are inadequate and missing. In addition, background concentrations used in the analysis may be subject to debate as water quality in a large watershed such as the Price River may be continuously changing due to natural mechanisms alone. From a management viewpoint, future monitoring should focus on obtaining continuous and spatially-distributed data on a regular basis with emphasis on missing data such as dissolved oxygen and heavy metals. Water data collection programs should be coordinated with all interested parties such as mining companies, US Forest Service, US Geological Survey, Utah Department of Natural Resources, and Water Conservancy Districts so that resources are allocated efficiently and effectively to obtain continuous, uninterrupted, and spatially-distributed data of all parameters of concern. Any future studies should focus on detailed tracer studies, water balance, surface water quality modeling for future management of the land, and quantification of recharge to streams and springs through base flow and/or surface runoff. The last item is of great importance as previous studies have speculated that major portions of recharges to Eccles and Mud Creeks are from base flow channeled through faults associated flow networks. If this is true, then the water flow and quality of these streams are controlled by subsurface processes too.

LIST OF TABLES

Table 1. Types and sources of data used in the analysis. 37

Table 2. Description of monitoring stations selected in the analysis of coal mining areas of Price River Watershed. 44

Table 3. Range of background concentrations and MCLs of selected parameters used in the analysis of data from the White Oak and Skylines Mines. The data for the Huntington Watershed were from Kaluarachchi and Abdin (1998b). 50

Table 4. Summary water quality data at Stream Station 173476 of Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC. 52

Table 5. Summary water quality data at Stream Station 173477 of Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC. 54

Table 6. Summary water quality data at Spring 173483 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC. 55

Table 7. Summary water quality data at Ground Water Well 173781 in Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC. 61

Table 8. Summary water quality data at Stream Station 173414 of upper South Fork of the Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 63

Table 9. Summary water quality data at Stream Station 173478 of South Fork in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC. 64

Table 10. Summary water quality data at Spring 173438 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 66

Table 11. Summary water quality data at Mine Discharge Station 173426 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 72

Table 12. Summary water quality data at Mine Discharge Station 173424 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 73

Table 13. Summary water quality data at UPDES Discharge Station 173448 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 74

Table 14. Summary water quality data at Seep 173425 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC 76

Table 15. Summary water quality data at Stream Station 173417 of upper Left Fork of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 77

Table 16. Summary water quality data at Stream Station 173415 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 78

Table 17. Summary water quality data at Stream Station 173428 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 80

Table 18. Summary water quality data at Stream Station 09310600 of Eccles Creek in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC. 82

Table 19. Summary water quality data at Stream Station 173418 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 83

Table 20. Summary water quality data at Stream Station 173452 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 84

Table 21. Summary water quality data at Spring 173431 in the Price River Watershed obtained from Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC 87

Table 22. Summary water quality data at Spring 173435 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC 89

Table 23. Summary water quality data at Stream Station 173480 of Finns Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 104

Table 24. Summary water quality data at Spring 173484 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 105

Table 25. Summary water quality data at Stream Station 173479 of Boardinghouse Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 108

Table 26. Summary water quality data at Stream Station 09310575 of Boardinghouse Canyon in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC 110

Table 27. Summary water quality data at Spring 173486 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 111

Table 28. Summary water quality data at UPDES Discharge Station 173449 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 115

Table 29. Summary water quality data at Stream Station 173475 of Mud Creek in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 117

Table 30. Summary water quality data at Stream Station 173474 of Mud Creek in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC 118

Table 31. Summary water quality data at Stream Station 09310700 of Mud Creek in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC. 120

Table 32. Summary water quality data at Groundwater Well 173451 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC. 125

Table 33. Summary water quality data at Stream Station 173419 of Burnout Creek in the Huntington Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC 128

Table 34. Summary water quality data at Spring 173440 in the Huntington Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC 130

Table 35. Range of background concentrations and MCLs of selected 132

Table 36. Summary water quality data at Stream Station 173300 of Wild Cattle Hollow in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 133

Table 37. Summary water quality data at Spring 173316 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 135

Table 38. Summary water quality data at Spring 173339 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 138

Table 39. Summary water quality data at Groundwater Well 173345 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 139

Table 40. Summary water quality data at Groundwater Well 173344 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 141

Table 41. Summary water quality data at Groundwater Well 173350 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 143

Table 42. Summary water quality data at Mine Interception Station 173575 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 145

Table 43. Summary water quality data at Mine Interception Station 173353 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 148

Table 44. Summary water quality data at Mine Interception Station 173354 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 150

Table 45. Summary water quality data at Mine Interception Station 173352 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 152

Table 46. Summary water quality data at Stream Station 173297 of North Fork of the Right Fork Miller Creek in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 155

Table 47. Summary water quality data at Stream Station 173295 of North Fork of the Right Fork Miller Creek in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 157

Table 48. Summary water quality data at Spring 173320 in the Price River Watershed obtained from the Star Point Mine. All units are in mg/l unless specified and bold lines indicate COC..... 160

Table 49. Summary water quality data at Spring 173318 in the Price River Watershed obtained from the Star Point Mine. All units are in mg/l unless specified and bold lines indicate COC..... 162

Table 50. Summary water quality data at Spring 173326 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC..... 163

LIST OF FIGURES

Figure 1. Location of the Manti-La Sal National Forest in Utah (from the visitor map of the Manti-La Sal National Forest, USFS, 1989)..... 17

Figure 2. Map of the Price River Watershed (from Lindskov, 1986)..... 18

Figure 3. A sketch of geological formations present in the study area (Lines and Plantz, 1981). 22

Figure 4. Details of the permitted land of the White Oak Mine with all available monitoring stations. 25

Figure 5. Cross-section AA' through the White Oak Mine. 27

Figure 6. Cross-section BB' through the White Oak Mine. 28

Figure 7. Details of the permitted land of the Skyline Mine with all available monitoring stations. 29

Figure 8. Cross-section AA' through the Skyline Mine..... 31

Figure 9. Cross-section AA' through the Skyline Mine..... 32

Figure 10. Details of the permitted land of the Starpoint Mine with all available monitoring stations. 33

Figure 11. Cross-section AA' through the Starpoint Mine. 35

Figure 12. Cross-section BB' through the Starpoint Mine..... 36

Figure 13. Locations of the monitoring stations in the White Oak Mine selected for the analysis..... 39

Figure 14. Locations of the monitoring stations in the Skyline Mine selected for the analysis. 41

Figure 15. Locations of the monitoring stations in the Starpoint Mine selected for the analysis..... 42

Figure 16. Time-series distributions of (a) precipitation and (b) evapotranspiration..... 48

Figure 17. Time-series distributions of flow at stations (a) 173477 and (b) 173476. 53

Figure 18. Time-series distribution of flow at Spring 173483. 56

Figure 19. Time-series distribution of iron at Station 173483..... 57

Figure 20. Time-series distributions of (a) TDS, (b) iron, and (c) manganese at Station 173477. 58

Figure 21. Time-series distributions of iron and manganese at Station 173483. 59

Figure 22. Time-series distributions of flow at Stations 173414 and 173478..... 62

Figure 23. Time-series distribution of flow at Station 173438..... 65

Figure 24. Time-series distributions of iron and manganese at Station 173414. 67

Figure 25. Time-series distributions of TDS, iron, and manganese at Station 173478..... 68

Figure 26. Time-series distributions of iron and manganese at Station 173438. 69

Figure 27. Time-series distributions of flow at Stations 173426, 173424, 173448, and 173425. 71

Figure 28. Time-series distributions of flow at Stations 173417, 173415, and 173428..... 79

Figure 29. Time-series distributions of flow at Stations 09310600, 173418, and 173452.... 85

Figure 30. Time-series distributions of flow at Stations 173431, and 173435..... 86

Figure 31. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173426. 90

Figure 32. Time-series distributions of TDS, iron, and sulfate at Station 173424..... 91

Figure 33. Time-series distributions of TDS, iron, and sulfate at Station 173448..... 93

Figure 34. Time-series distributions of TDS, iron, and manganese at Station 173425..... 94

Figure 35. Time-series distributions of TDS and manganese at Station 173417. 95

Figure 36. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173415. 96

Figure 37. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173428. 97

Figure 38. Time-series distributions of iron and manganese at Station 09310600. 98

Figure 39. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173418. 99

Figure 40. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173452. 100

Figure 41. Time-series distributions of iron and manganese at Station 173431. 102

Figure 42. Time-series distributions of iron and manganese at Station 173435. 102

Figure 43. Time-series distributions of flow at Stations 173480 and 173484. 103

Figure 44. Time-series distributions of flow at Stations 173479, 173575, and 173486. 107

Figure 45. Time-series distributions of iron and manganese at Station 173479. 112

Figure 46. Time-series distributions of iron and manganese at Station 09310575. 113

Figure 47. Time-series distributions of iron and manganese at Station 173486. 113

Figure 48. Time-series distributions of flow at Stations 173449, 173475, and 173474. 116

Figure 49. Scofield reservoir discharge to Price River. 121

Figure 50. Time-series distributions of TDS and iron at Station 173449. 122

Figure 51. Time-series distributions of TDS and iron at Station 173475. 122

Figure 52. Time-series distributions of TDS, manganese, and sulfate at Station 173474. 123

Figure 53. Time-series distributions of TDS, iron, and sulfate at Station 173451. 126

Figure 54. Time-series distributions of flow, iron, and sulfate at Station 173419. 127

Figure 55. Time-series distribution of flow at Station 173440. 129

Figure 56. Time-series distribution of flow at Station 173300. 134

Figure 57. Time-series distributions of flow and iron at Station 173316. 136

Figure 58. Time-series distributions of flow and iron at Station 173339. 137

Figure 59. Time-series distributions of flow and manganese at Station 173345. 140

Figure 60. Time-series distributions of flow and manganese at Station 173344. 142

Figure 61. Time-series distribution of iron at Station 173350..... 144

Figure 62. Time-series distributions of flow, TDS, and sulfate at Station 173575. 146

Figure 63. Time-series distributions of flow, TDS, and iron at Station 173353. 149

Figure 64. Time-series distributions of flow, TDS, iron, and sulfate at Station 173354..... 151

Figure 65. Time-series distributions of flow, TDS, and sulfate at Station 173352. 153

Figure 66. Time-series distributions of flow, TDS, and sulfate at Station 173297. 156

Figure 67. Time-series distributions of flow, TDS, and sulfate at Station 173295. 158

Figure 68. Time-series distribution of flow at Station 173330..... 159

Figure 69. Time-series distribution of flow at Station 173320..... 161

Figure 70. Time-series distribution of flow at Station 173318..... 164

Figure 71. Time-series distributions of flow, iron, and manganese at Station 173326. 165

1.0 INTRODUCTION

The Manti-La Sal National Forest is located in south-central Utah and covers approximately 1.2 million acres of land (see Figure 1). The forest land is administered by the US Forest Service Supervisor's Office in Price. The Manti Division of the Manti-La Sal National Forest encompasses approximately 79,000 acres of land which includes a substantial portion of the Wasatch Plateau. The Wasatch Plateau is located east of Castle Valley and west of Sanpete Valley. The elevation in the national forest varies from 5,300 feet to 11,238 feet above mean sea level. The Manti Division includes areas from Emery, Carbon, Sevier, and Sanpete Counties.

The Manti Division has several well-defined watersheds, and this study is focused on coal mining areas of the Price River Watershed (see Figures 1 and 2). The main tributary of the Price River Watershed is the Price River which flows in a southeastern direction. The Price River joins the Green River which flows in a southern direction to join the Colorado River. Cottonwood Canyon joins the San Rafael River which flows in a southeastern direction. San Rafael River merges with the Green River which, in turn, merges with the Colorado River about 30 miles south of Moab.

The national forest land is managed under a multiple-use sustained-yield management system. The different land uses in the national forest include coal mining, livestock grazing, agriculture, recreation, fish and wildlife habitat, timber harvesting, and watershed management. Of these activities, coal mining is the economically strong land use in the national forest and provides much needed economic support to local communities as well as to the State of Utah. In the Manti Division, there are a number of active and reclaimed coal mines. Coal mining in this region is performed as subsurface mining and has been ongoing for at least 30 years. Mine permitting and subsequent operations are administered and supervised by the Utah Department of Natural Resources through the Division of Oil, Gas, and Mining (DOGM) and the Forest Supervisor's Office in Price. The water flow and quality measurements from surface water pathways, ground water monitoring wells, mine interceptions, mine discharges, and springs are monitored by mining companies on a

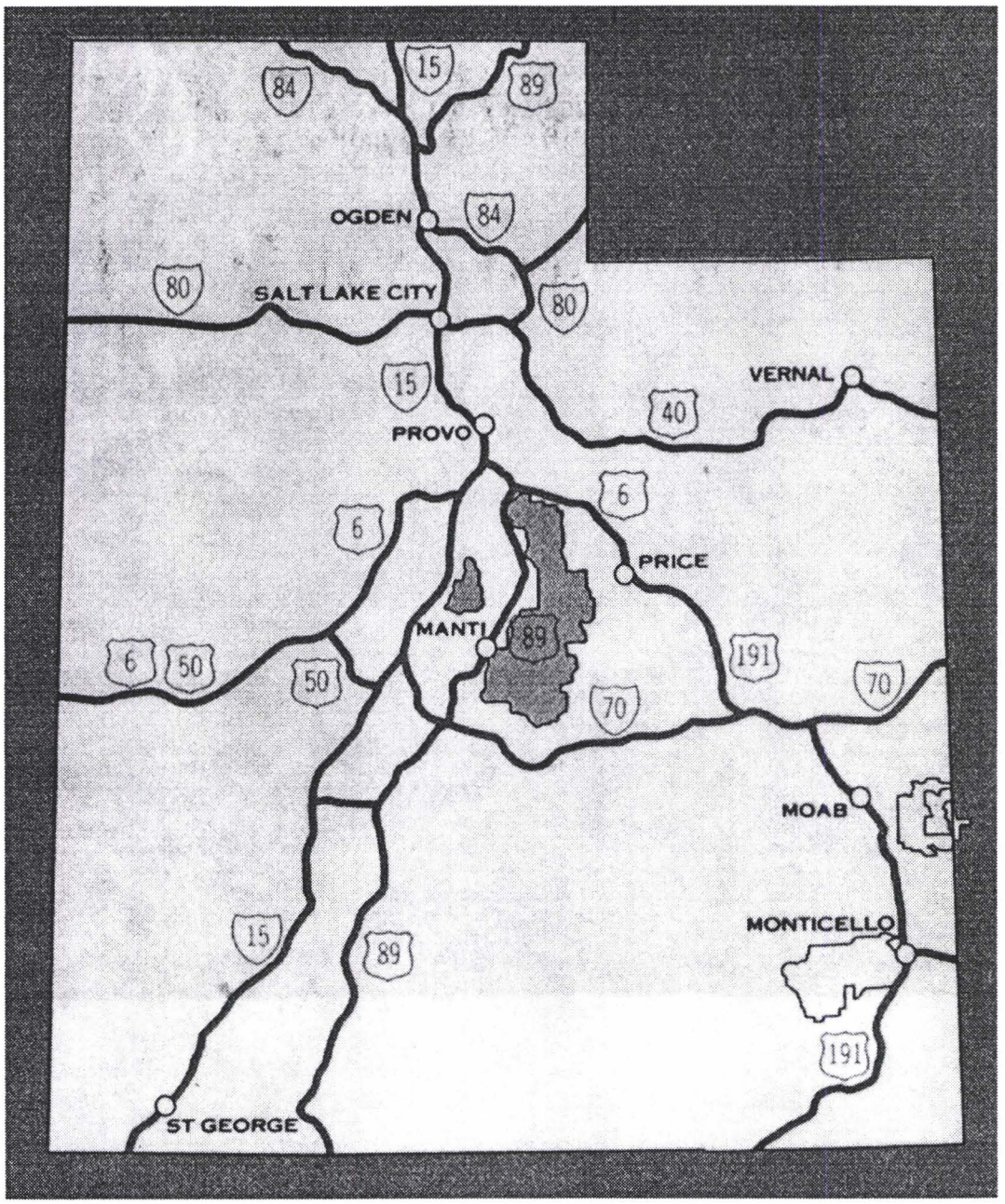


Figure 1. Location of the Manti-La Sal National Forest in Utah (from visitor map of the Manti-La Sal National Forest, USFS, 1989).

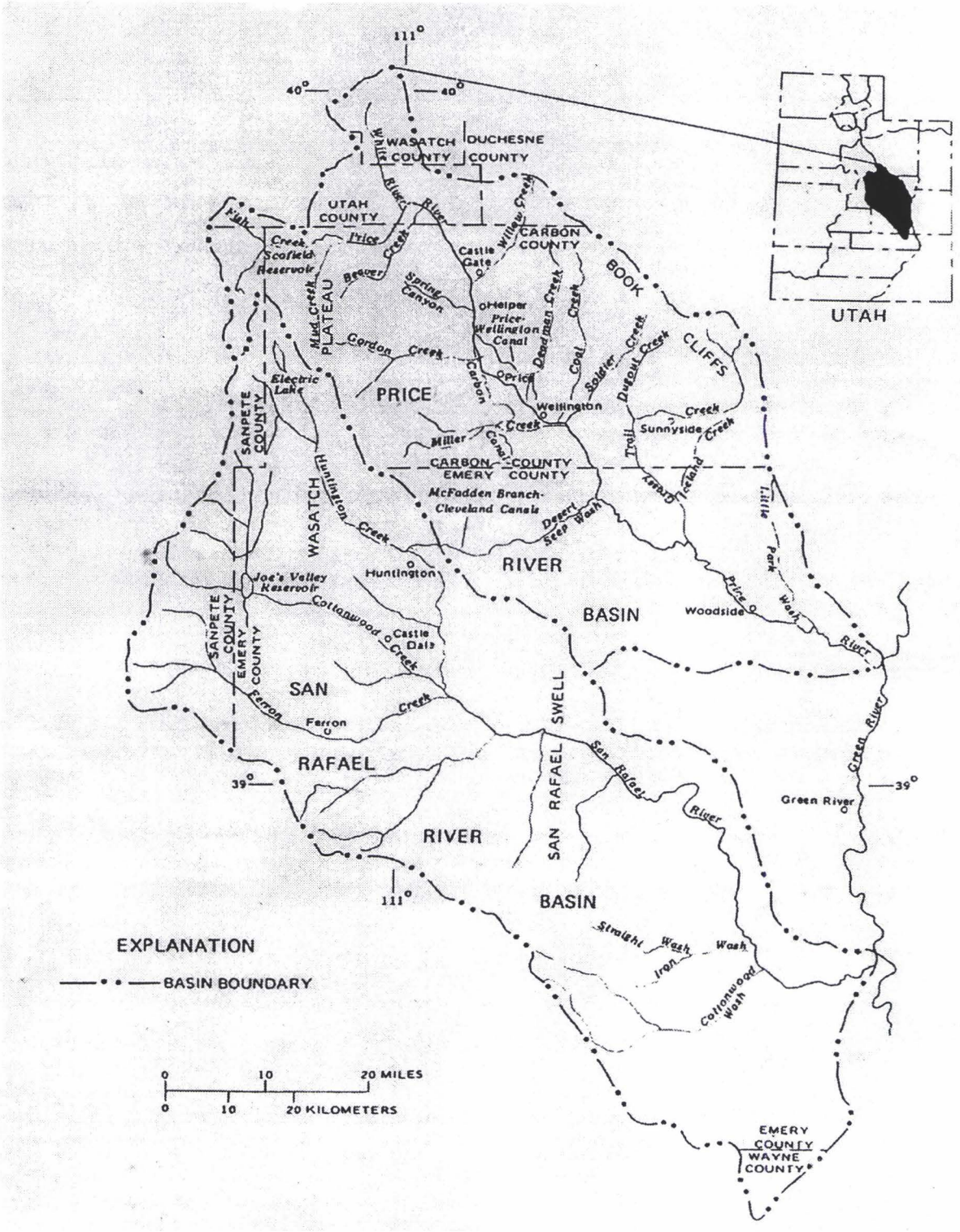


Figure 2. Map of the Price River Watershed (from Lindskov, 1986).

quarterly basis and reported to DOGM. These measurements are entered into the APPX data base of the Division of Water Quality, Utah Department of Environmental Quality. The computer data base is operated and maintained by the Computer Division of the Utah Department of Health. These frequent monitorings are required by law to ensure that the existing pattern of water distribution and movement within the national forest land is not affected such that downstream water users can benefit from the existing water.

Although rigorous monitoring of water flow and quality is required by law, there have been concerns by various downstream land users that water flow and quality have been affected over the past years. These concerns have been raised due to the lack of adequate water for various activities, especially for agriculture and livestock grazing. Although there is no substantial evidence todate to establish that any of the land uses including coal mining is responsible for these changes, the concerns have focused on existing mining activities. In order to better understand the historical changes in water flow and quality and the current status, the Utah Water Research Laboratory (UWRL) of Utah State University has undertaken this study with funding from the US Forest Service through a cooperative agreement between the UWRL and the Intermountain Research Station of the US Department of Agriculture, Forest Service.

2.0 PROJECT OBJECTIVES

The overall goal of this work is to better understand the current status of water flow and quality, especially in coal mining areas of the Price River Watershed. It should be noted that a portion of the Price River Watershed does not fall within the national forest land, and instead, a majority is private land and land administered by the Bureau of Land Management. However, a large part of the Price River Watershed with mining activities is located near the boundary between the Price River and Huntington Watersheds. Therefore, this study will focus on mining areas of the Price River Watershed and overlapping land within the Huntington Watershed. The specific mines focused in this study will be White Oak, Skyline, and Starpoint.

This study will use the existing data and has no provision to collect additional data. Therefore, the results and conclusions drawn from the study will be subject to the quality and adequacy of historical data. Subject to these conditions, the specific objectives of the proposed study will be as follows:

1. Determine the existing meteorological and water-related data from various federal, state, and local agencies.
2. Using the data obtained from Objective (1), perform the necessary analysis to determine the current status and historical changes of water flow and quality in mining areas of the watershed.
3. Using the results obtained from Objective (2), assess the impact of historical changes of water flow and quantity and provide necessary recommendations to improve the existing water monitoring program.

The research approach of the study, including the selection of monitoring stations and statistical analysis, remains the same as that of the Cottonwood and Huntington Watersheds given in Parts I and II of this document series (Kaluarachchi and Abdin, 1998a, 1998b).

Previous water-related studies conducted at the Manti Division of the Manti-La Sal National Forest (Danielson et al., 1981; Danielson and Sylla, 1983; Evangelou et al., 1984; Lindskov, 1986; Williams, 1975) were discussed in Document Part I of the Cottonwood Watershed.

3.0 PRICE RIVER WATERSHED

3.1 Introduction

The Price River Watershed includes approximately 1800 square miles of land area in six counties (Figure 2), and primarily covers Carbon and Emery Counties. The watershed occupies parts of the three physiographic sections of the Colorado Plateau; Uinta Basin to the north, High Plateaus to the west, and Canyon Lands to the south and east (Fenneman, 1946). The Price River Watershed originates in the Wasatch Plateau about 12 miles west and south of Scofield Reservoir. The watershed is bounded by the Book Cliffs on the northeast, the Wasatch Plateau on the west, and the San Rafael Swell on the south. The altitude of the watershed varies from greater than 10,000 feet in the headwaters to about 4,200 feet at the mouth where the Price River joins the Green River.

Scofield Reservoir, which has a usable capacity of 65,780 acre-feet, regulates approximately 10% of the upstream flow of the Price River Watershed. The White River and Willow Creek are major streams contributing flow to the Price River between Scofield Reservoir and the points of diversion to the Price-Wellington and Carbon Canals.

The major surface water pathway of the watershed is Price River which begins at the northwest corner and drains to Scofield Reservoir. Mud Creek, also known as Pleasant Creek, drains to Scofield Reservoir from the south. The White River joins Price River just above the Utah-Carbon County line, and the Price River changes direction and flows towards the southwest. The major discharges to the Price River occurs through Beaver Creek, Willow Creek, Spring Canyon, Gordon Creek, Coal Creek, Soldier Creek, and Miller Creek.

3.2 Hydrogeology

The geology of the study area is similar to the description of the Huntington Watershed (Kaluarachchi and Abdin, 1998b), and the common geological formations are shown in Figure 3. The only difference is that the Colton and Green River Formations are located

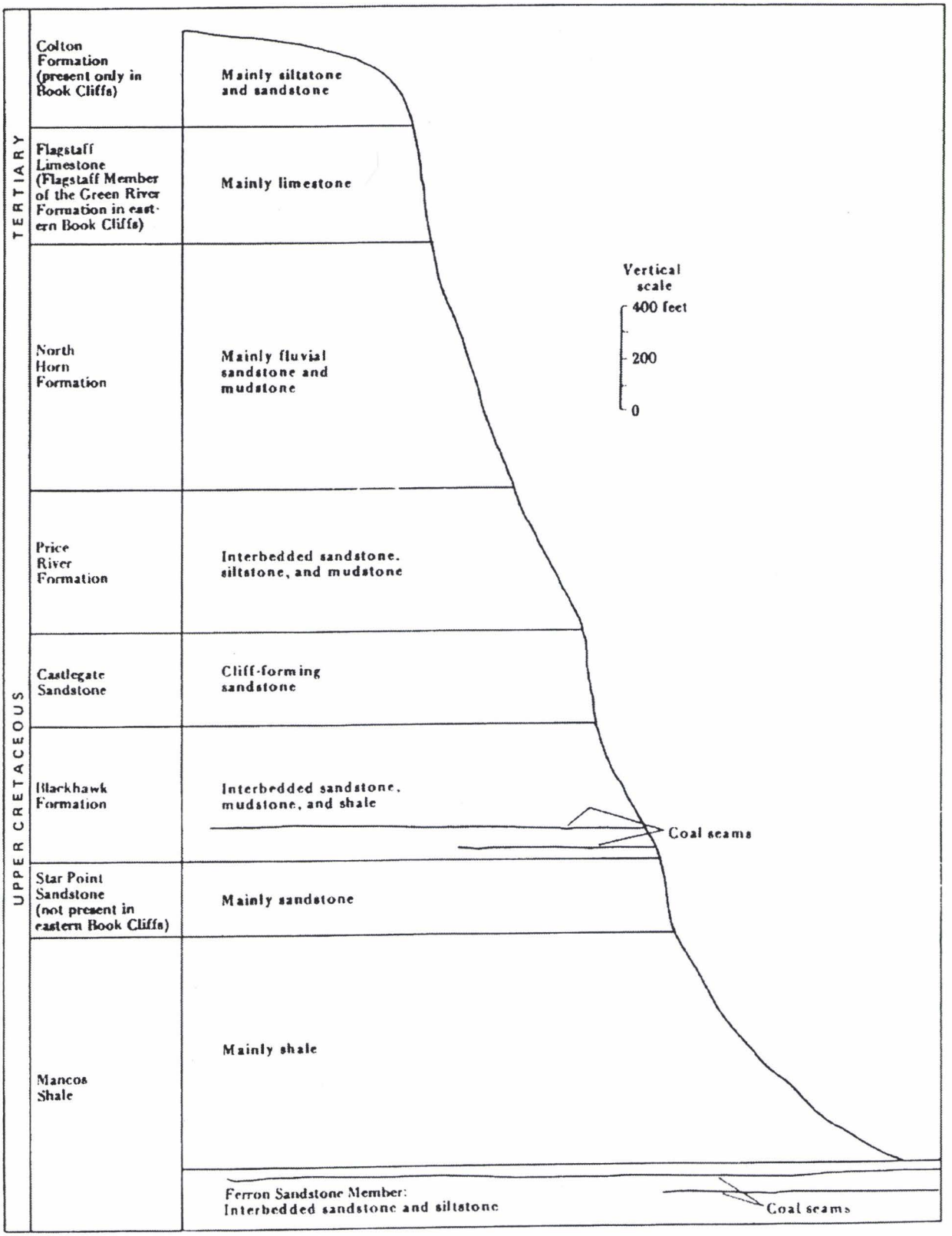


Figure 3. A sketch of geological formations present in the study area (from Lines and Plantz, 1981).

above the Flagstaff Formation (Crandall Canyon Mine Permit Documentation, 1996). The top-most formation is the Green River Formation, and this stratum consists of greenish lacustrine shale and siltstone. The Colton Formation consists of shale with sandstone and limestone lenses. The combined thickness of both formations can vary from 300 to 1,500 feet. The remaining formations and their respective hydrogeological characteristics are similar to that of the Huntington Watershed and are given in Figure 3.

Rocks that crop out in coal-producing areas of the watershed consist mainly of sandstone, mudstone, and shale (Lindskov, 1986). The Blackhawk Formation of the cretaceous age is the most important coal-producing unit. Coal is mined from the Blackhawk Formation in the Wasatch Plateau and Book Cliffs with underground techniques. Except for some areas of the Book Cliffs where the Blackhawk Formation inter-tongues with the Mancos Shale of the cretaceous age, the Blackhawk Formation is underlain by Starpoint Sandstone of the cretaceous age. The Blackhawk Formation in most coal-producing areas is overlain by about 2,000 feet of mainly sandstone and mudstone. The highest areas of the Wasatch Plateau are capped by cliff-forming limestone in the Flagstaff Limestone of the tertiary age, whereas in the Book Cliffs, the highest areas are usually capped by the Colton Formation of the tertiary age.

Shales in the Mancos Shale that overlie the Ferron Sandstone generally crop out along the downstream reaches of tributaries to the Price River. The Mancos Shale is the predominant geologic influence on the chemical quality of water that enters the Price River downstream from Helper.

While the US Geological Survey (USGS) has indicated that a regional aquifer is present in the Blackhawk-Starpoint Formations (Lindskov, 1986), more recent information indicate that the Blackhawk Formation is only partially saturated in localized areas. Further, the Starpoint Sandstone Formation is not uniformly saturated, and has shown variable characteristics across the plateau. The low permeabilities in these units make them very questionable as a regional aquifer. Ground water flow direction is southwest in the White

Oak and Skyline Mine areas. In the Starpoint Mine area, ground water flow is to the southeast.

3.3 Coal Mining Activities

The Price River Watershed has a number of active and reclaimed mines. The actives mines closer to the Huntington Watershed boundary are White Oak and Skyline. The Starpoint Mine is located further southeast from the previous two mines. The Starpoint Mine is the largest followed by Skyline and White Oak Mines, based on the areas of mine permitted land. The Starpoint Mine also has the largest number of monitoring stations followed by Skyline and White Oak Mines. However, the Skyline Mine had the largest coal production followed by Starpoint and White Oak Mines according to the coal production data of 1996 and 1997.

3.3.1 White Oak Mine

White Oak Mine is located at the northwest corner of the Price River Watershed and in Carbon County (Figure 4). The mine is about 3 miles southwest of Scofield and 20 miles northwest of Price. The total permitted land area is about 700 acres. Before 1993, White Oak Mine was known as Belina Mine and it was owned and operated by Valley Camp of Utah, a subsidiary of Quaker Oil Company. Presently, White Oak Mine is owned and operated by White Oak Mining and Construction Company, Inc. The net coal production of the White Oak Mine in 1996 and 1997 was 1,069 and 886 thousand short tons, respectively. The National Weather Service rainfall gaging station is closest to the White Oak Mine and is located in Nephi. The average annual precipitation at this station is about 14.5 inches per year.

Figure 4 shows the permitted land area of the White Oak Mine with associated main surface water pathways. The monitoring stations indicated in the map are those listed with various agencies including the APPX data base. However, the data from most of these stations were limited at the time of the analysis or located in the Huntington Watershed. Therefore, a sub-

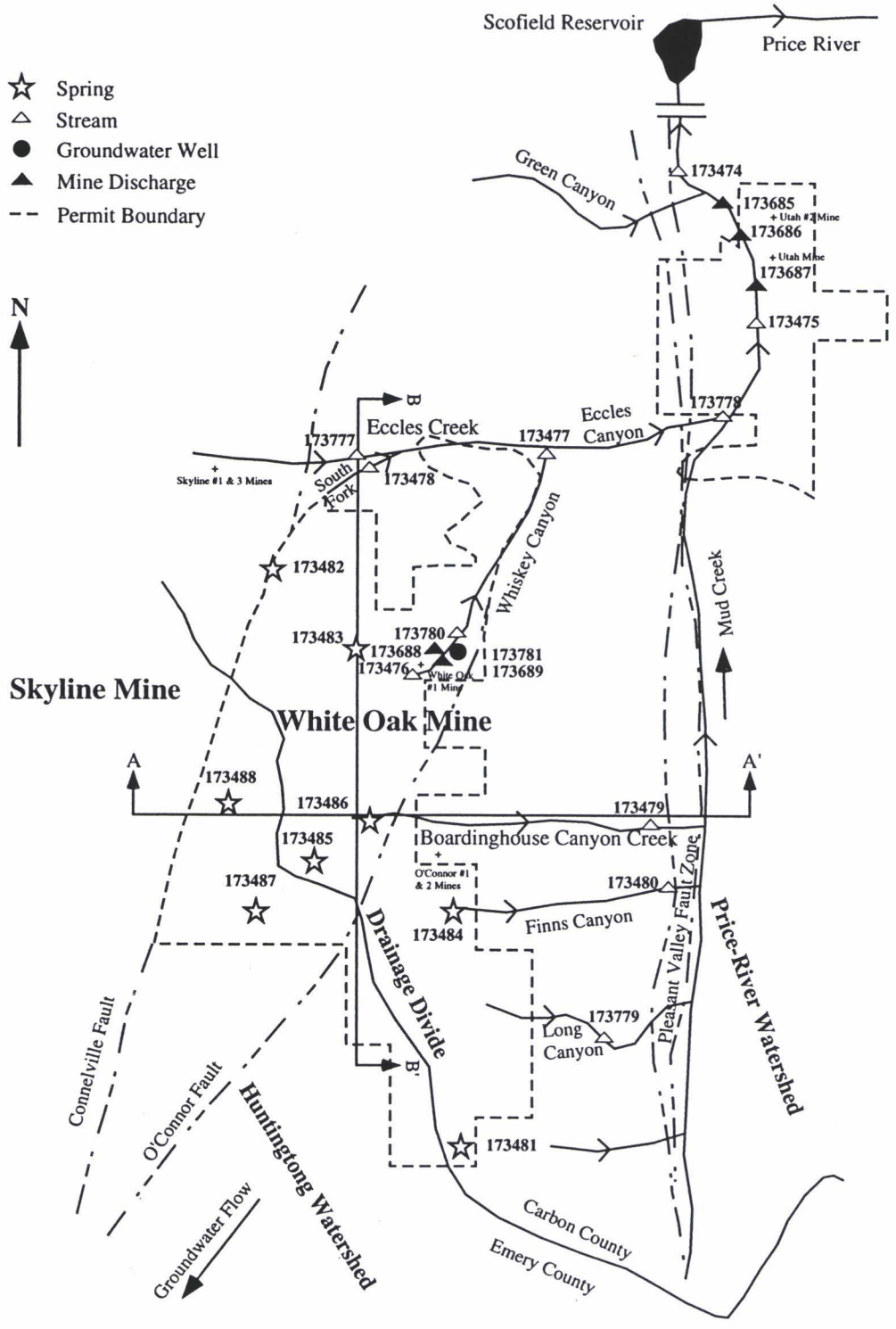


Figure 4. Details of the permitted land of the White Oak Mine with all available monitoring stations.

set of these stations was selected in the final analysis. A detailed discussion related to this selection will be given in Section 3.4.2.

The mine area is located between two faults, Connelville and O'Connor, and the Pleasant Valley Fault is located east of the mine. Figures 5 and 6 show the cross-sections through the mine area as indicated in Figure 4. Figure 5 shows that the permitted area has an overburden of approximately 1,500 to 1,800 feet. Since the drainage divide is located approximately through the mid-section of the permitted area, the surface runoff occurs towards both the east and west. Cross-section BB' shows a less steep terrain compared to the cross-section AA'. The water table is located approximately between the Blackhawk and the Starpoint Sandstone Formations, and the flow is towards the southwest (White Oak Mine Permit Documentation, 1984). The Starpoint Sandstone Formation is fractured and can be considered to be the first aquifer. The fractures are associated with the O'Connor and Connelville Faults. The lower Blackhawk and Starpoint Formations are considered to be one aquifer. Mancos Shale beneath the Starpoint Sandstone is a good aquiclude.

3.3.2 Skyline Mine

Skyline Mine is one of the largest mines in the area and is located northwest of White Oak Mine (Figure 7). The mine boundary extends to both Emery and Carbon Counties as well as to both the Huntington and Price River Watersheds. Skyline Mine is owned and operated by Canyon Fuel Company, LLC. Mining started in this land around 1880 and has been on-going since that period. The combined coal production of Skyline Mines #1 and #3 in 1996 and 1997 was 4,454 and 4,315 thousand short tons, respectively.

Figure 7 shows the details of the mine permitted area of Skyline Mine. As discussed earlier, only a sub-set of the monitoring stations shown on the map was used in the final analysis. Skyline Mine is located between North Joe's Valley and Connelville Faults. The Connelville Fault is the largest and most continuous fault with a 200 feet combined displacement producing the largest adjustment along the southern part of the mine (Skyline Mine Permit Documentation, 1979). Valentine Fault is a split from the Connelville Fault near the

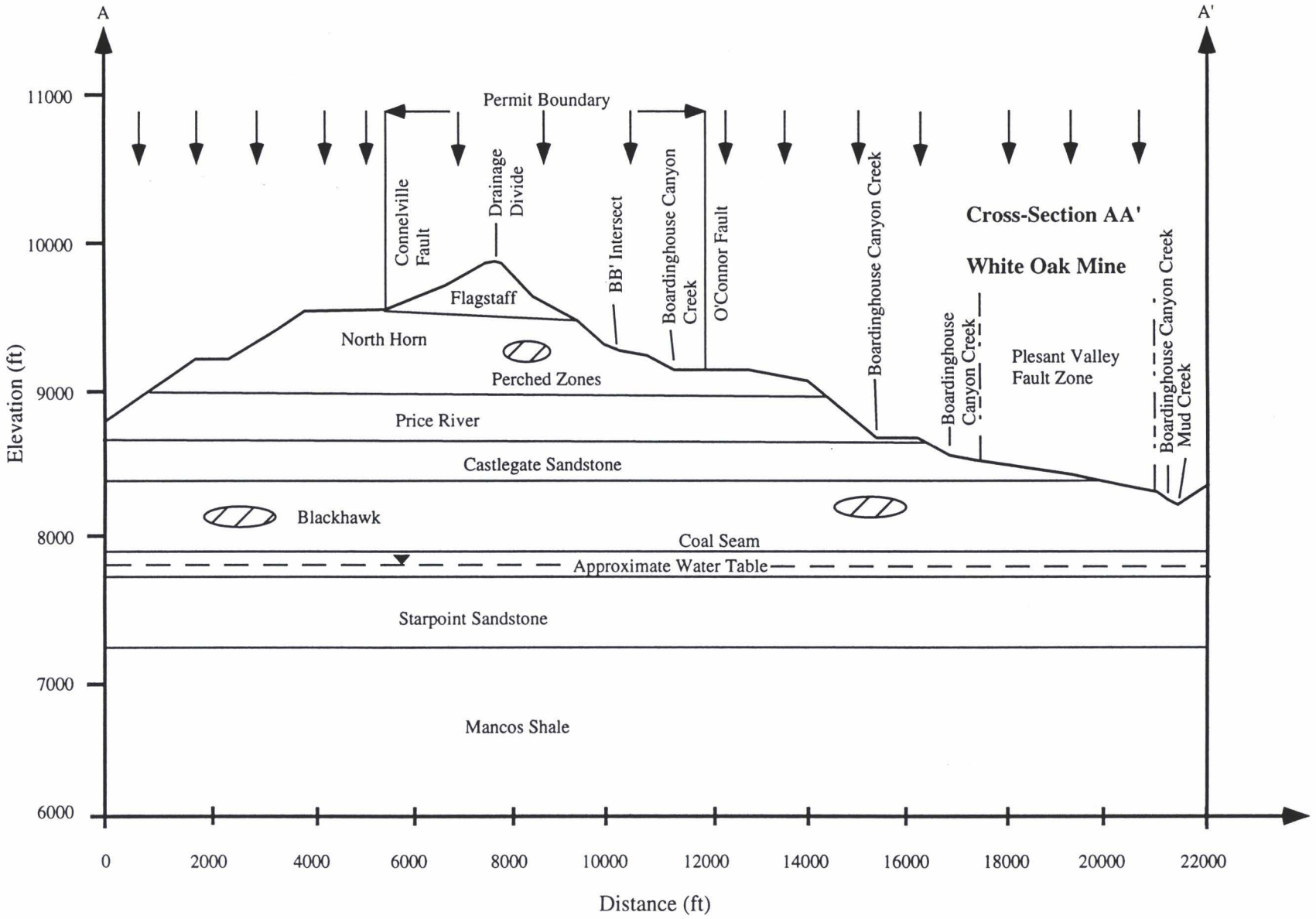


Figure 5. Cross-section AA' through the White Oak Mine.

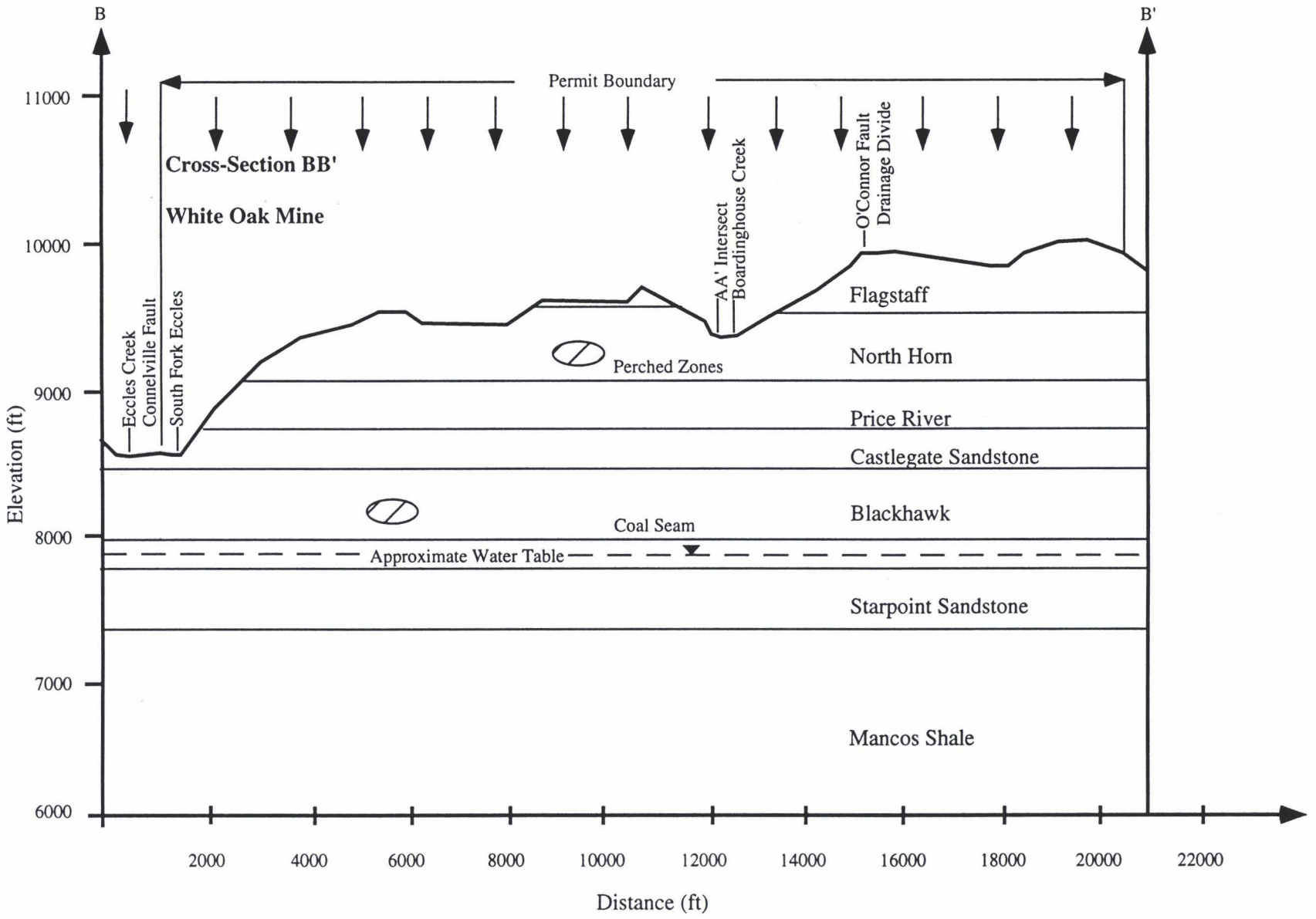


Figure 6. Cross-section BB' through the White Oak Mine.

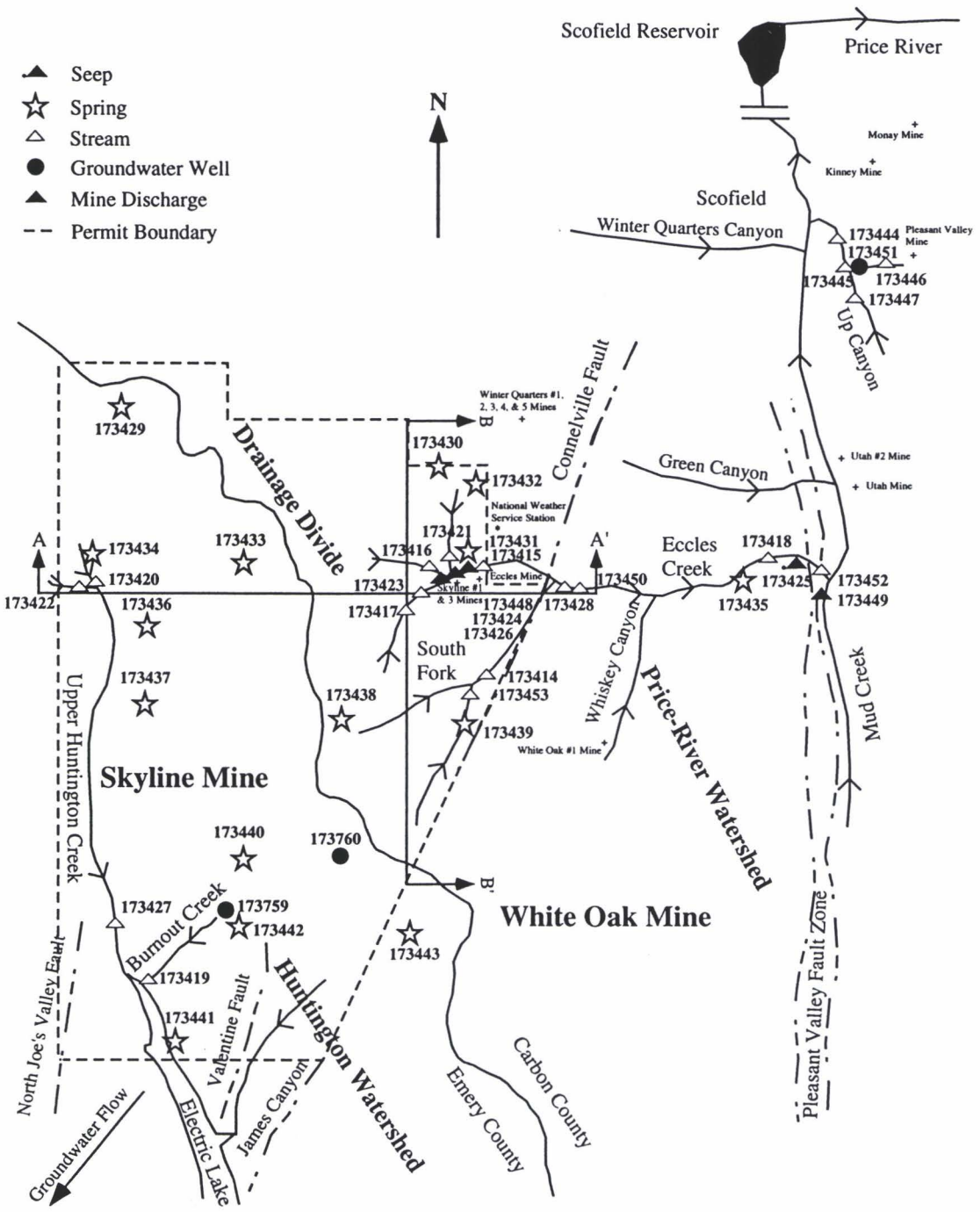


Figure 7. Details of the permitted land of the Skyline Mine with all available monitoring stations.

southern part of the property. This fault enters the mine property along James Canyon with an approximate displacement of 30 feet. North Joe's Valley Fault enters the mine property from the southwest corner and west of Electric Lake with a displacement of 80 to 100 feet. The displacement of North Joe's Valley Fault is reverse to the two previously discussed structures with the east moving down. Connelville Fault represents one segment of the North Joe's Valley Fault.

Figures 8 and 9 show the geological cross-sections through the mine permitted land. According to Figure 8, much of the overburden is in the Blackhawk Formation with an average overburden of about 1,200 feet. Cross-section BB' shows a less steep permitted area. The Blackhawk Formation, of thickness 700 to 1,000 feet, crops out over most of the area with only a small section of Castlegate Sandstone capping the ridges in the northwestern corner of the property. Castlegate Sandstone, of thickness 150 to 500 feet, is the only member of the Price River Formation exposed in the vicinity of the Skyline property. The Price River Formation, of 300 feet thickness, is exposed in the head of Winter Quarters Canyon, but thicker sections are evident to the north and west. The approximate location of the water table is between the Blackhawk and the Starpoint Sandstone Formations, and the ground water flows towards the southwest.

3.3.3 Starpoint Mine

The Starpoint Mine is located further south and to the east of White Oak and Skyline Mines (Figure 10). The mine is located about 12 miles southwest of Price, and extends to both Emery and Carbon Counties and the Price River and Huntington Watersheds. Starpoint Mine is owned and operated by the Cyprus Plateau Mining Company. The net coal production of the Starpoint Mine in 1996 and 1997 was 2,911 and 1,352 thousand short tons, respectively. The entrances to the underground workings are on the east face of the Wasatch Plateau. The surface facilities occupy approximately 173 acres which drain into sedimentation ponds. The sedimentation ponds drain into Serviceberry Creek. Water from the underground workings is generally pumped into old workings, but has been discharged at Mudwater Canyon through a NPDES discharge point. The surface water of the mine land

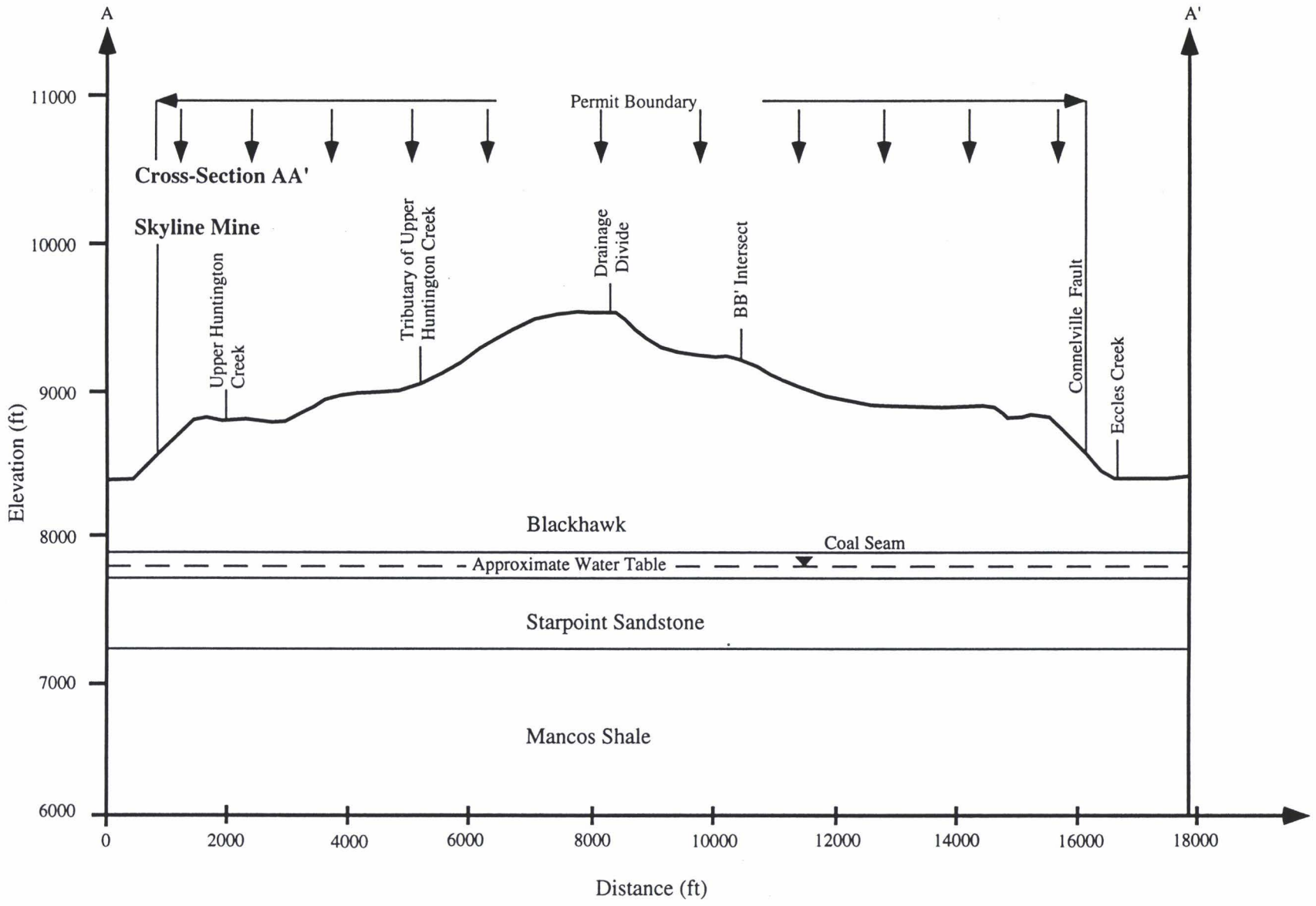


Figure 8. Cross-section AA' through the Skyline Mine.

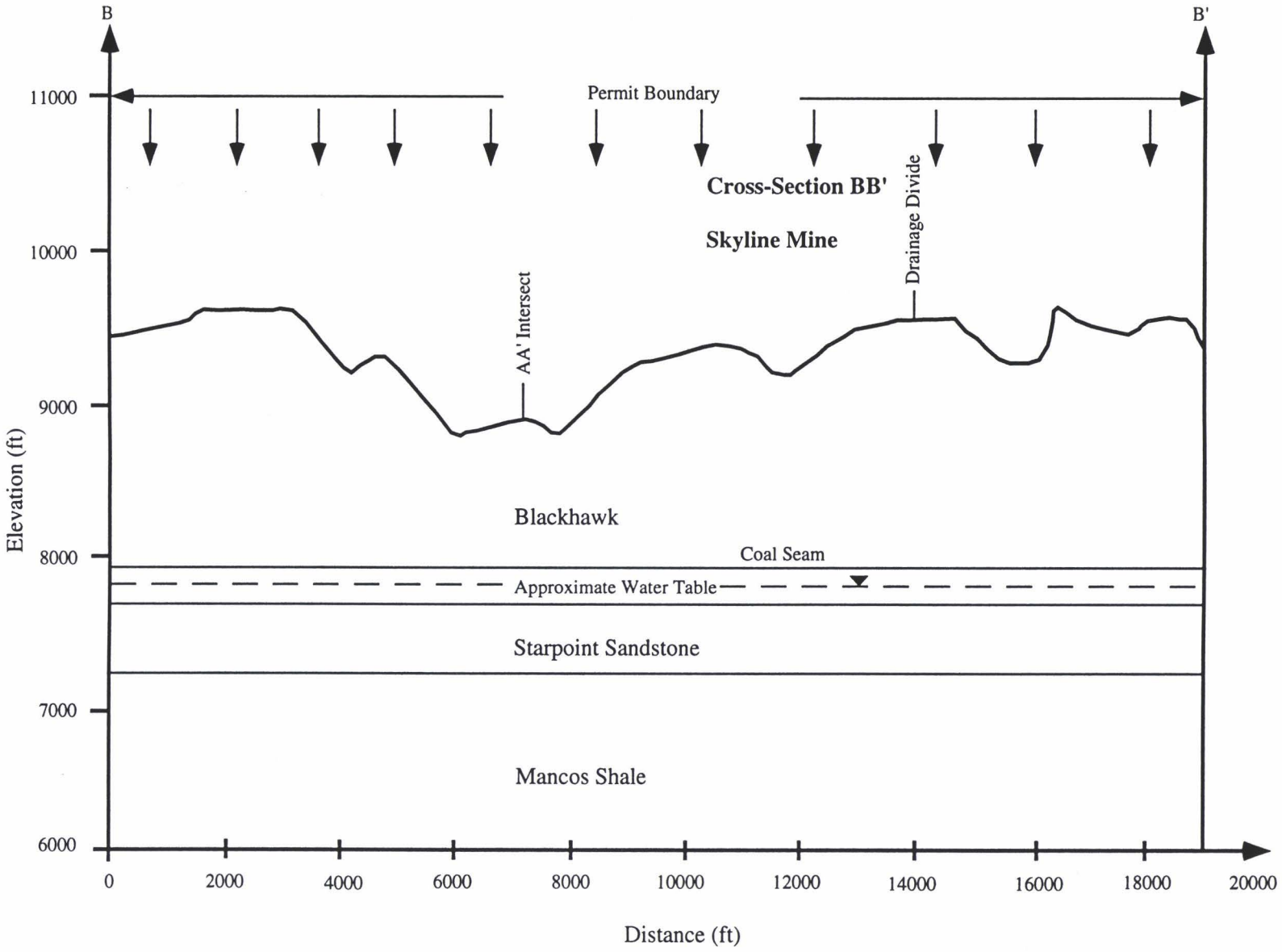


Figure 9. Cross-section BB' through the Skyline Mine.

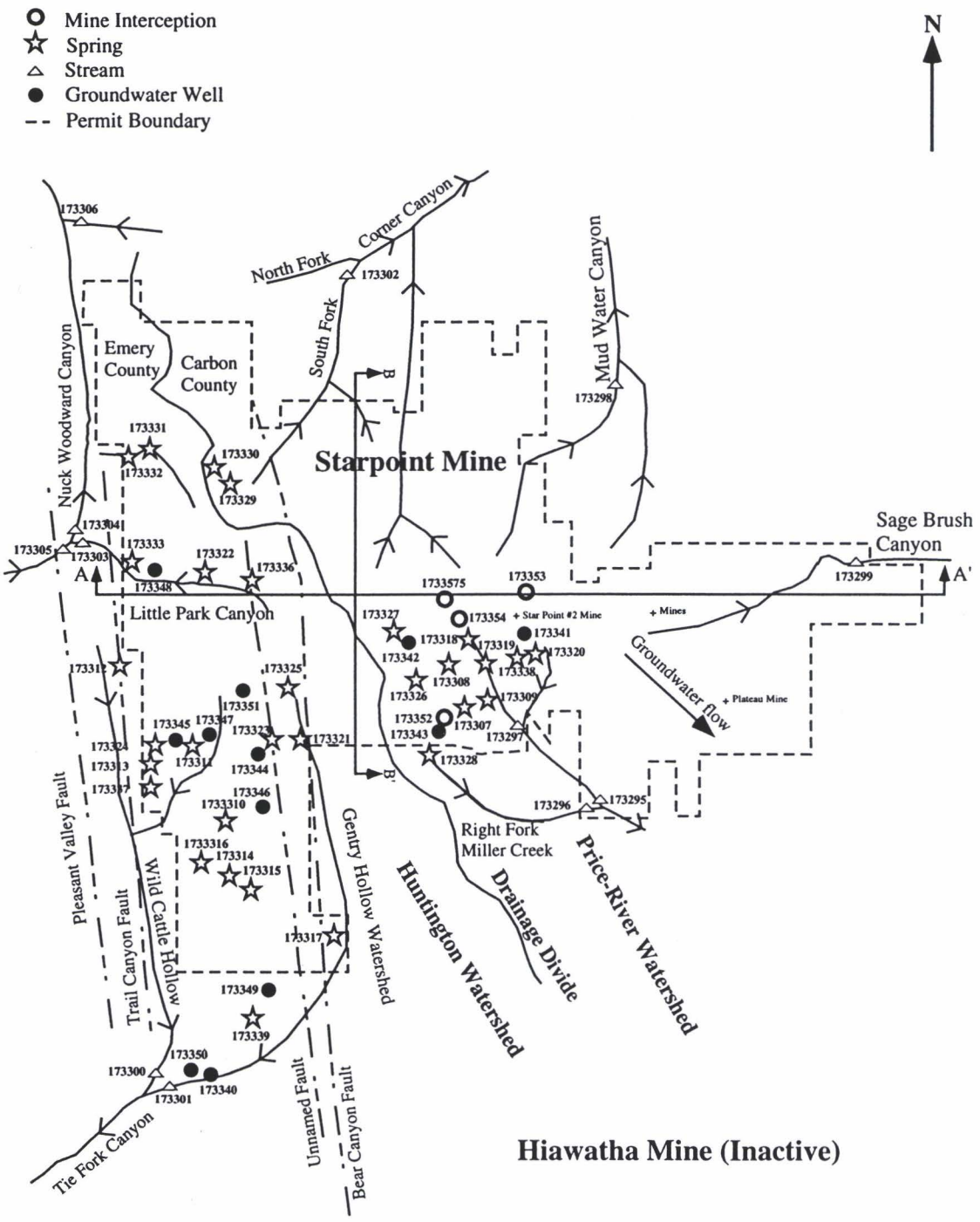


Figure 10. Details of the permitted land of the Starpoint Mine with all available monitoring stations.

drains to streams including Tie Fork Canyon, Right Fork Miller Creek, Mud Water Canyon, and Corner Canyon, and their tributaries.

Figure 10 shows the details of the mine permitted land of Starpoint Mine. Figures 11 and 12 show the geological cross-sections through the mine permitted land. Figure 11 shows a steep surface elevation to the east of the mine permitted area where the decrease is approximately 2,800 feet. Cross-section BB' shows a less steep mine permitted land through the north to the south. The approximate location of the water table is the same as in the previous two mines; between the Blackhawk and Starpoint Sandstone Formations (Starpoint Mine Permit Documentation, 1992). The flow direction of the ground water is towards the southeast.

In addition to these active mines, there are a number of other active mines in the Price River Watershed. These mines include Willow Creek, Aberdeen, and Soldier Canyon; all located in Carbon County. Willow Creek Mine is owned and operated by the Cyprus Plateau Mining Company. The net coal production of the Willow Creek Mine in 1996 and 1997 was 7 and 447 thousand short tons, respectively. Aberdeen Mine is owned and operated by Andalex Resources, Inc. The net coal production of the Aberdeen Mine in 1996 and 1997 was 2,449 and 1,872 thousand short tons, respectively. Soldier Canyon Mine is owned and operated by Canyon Fuel Company. The net coal production of the Soldier Canyon Mine in 1996 and 1997 was 977 and 1,150 thousand short tons, respectively.

All three mines described earlier are located in the Book Cliffs Coal Field outside the US Forest Service land and in the land administered by the Bureau of Land Management. Therefore, these three mines were not considered in the present study.

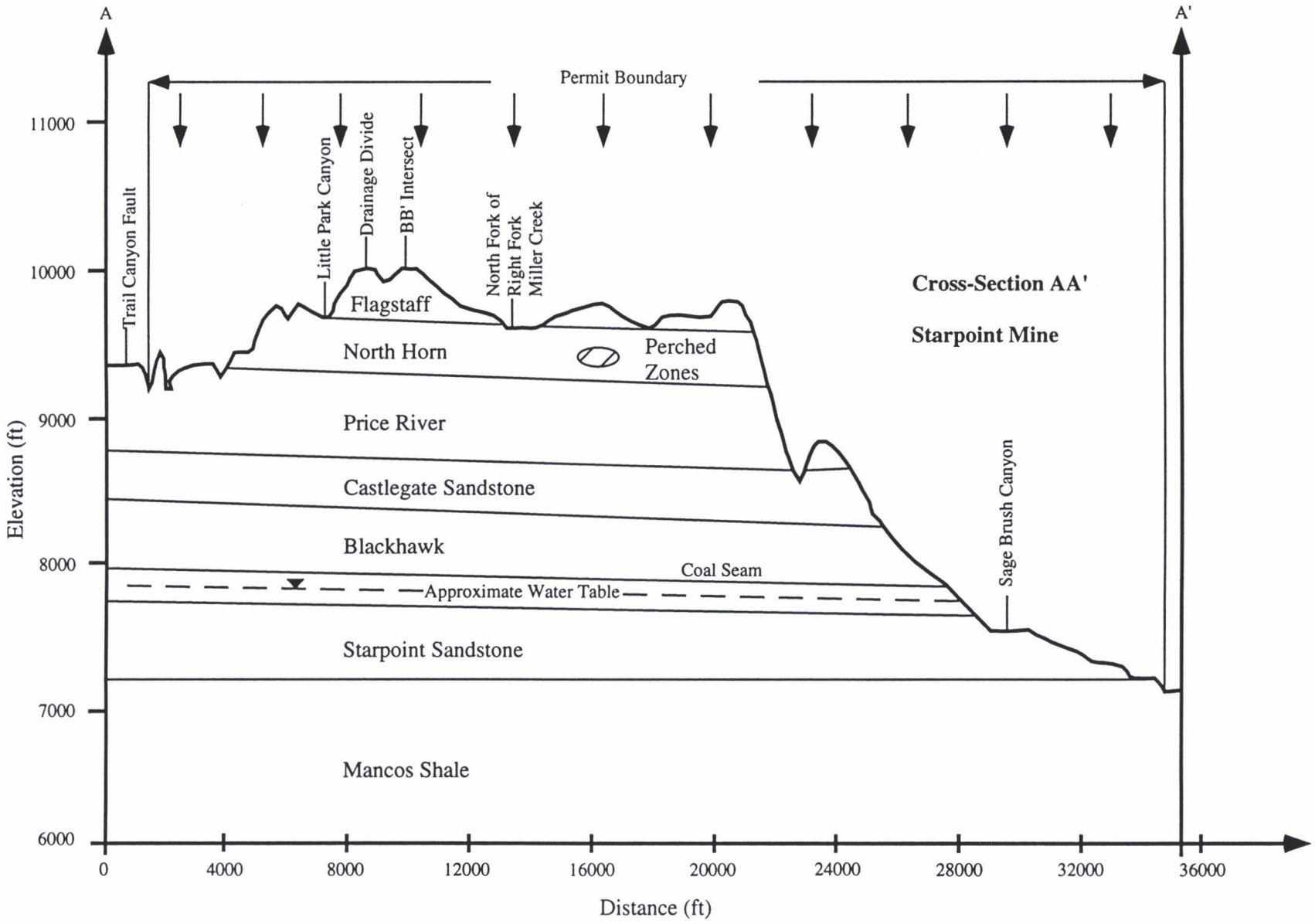


Figure 11. Cross-section AA' through the Starpoint Mine.

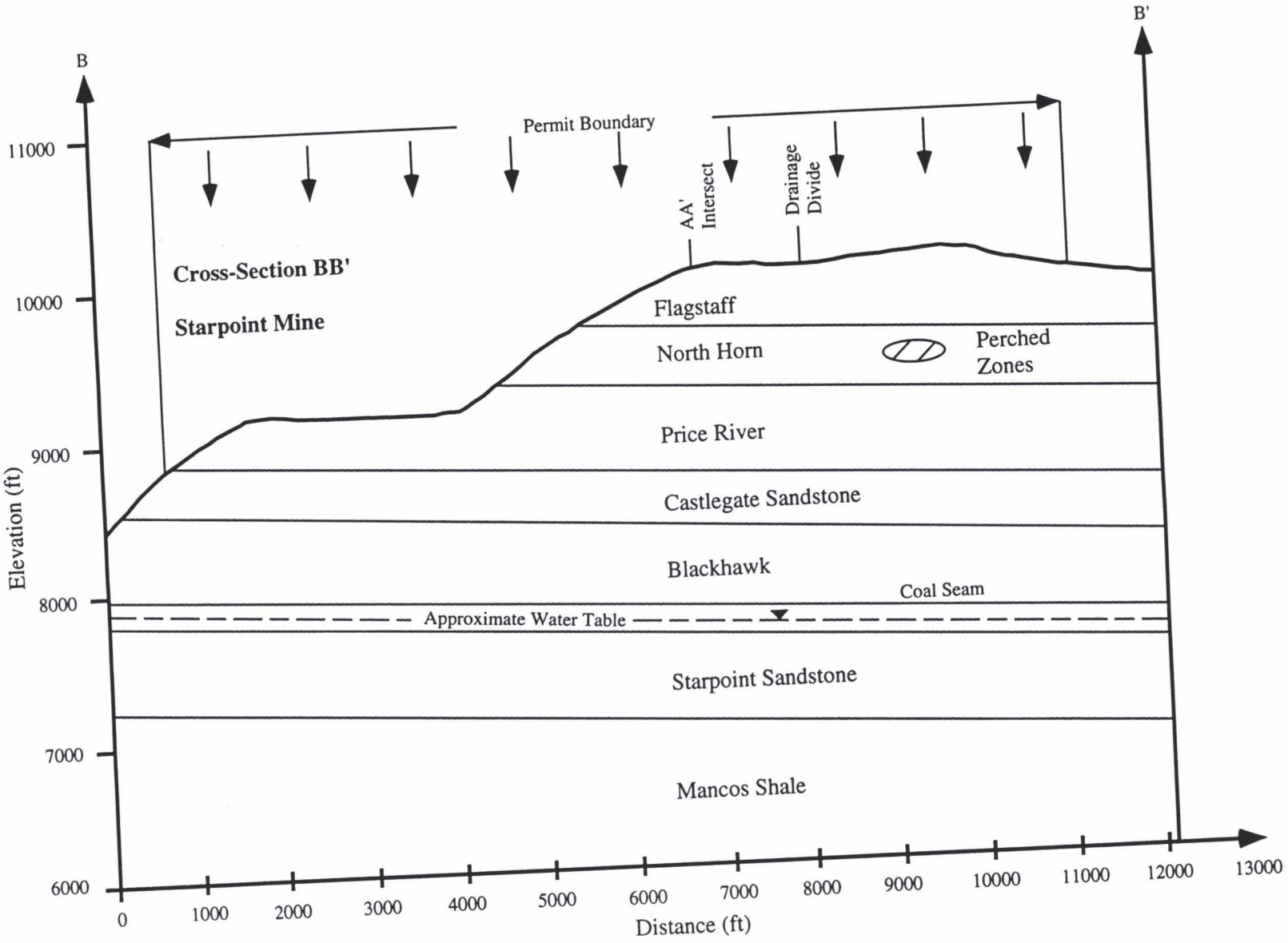


Figure 12. Cross-section BB' through the Starpoint Mine.

3.4 Analysis of Water-related Data

3.4.1 Types and Sources of Data

The types of data and the sources of data remain the same as in the Cottonwood and Huntington Watersheds except for the Emery Water Conservancy District (EWCD). The Emery Water Conservancy District provided useful data in the analysis of Huntington and Cottonwood Watersheds. However, there were no data available from the EWCD for the present study (personal communication with Jay Humphrey of EWCD).

There is no direct filtering process to assess the quality of the data for analysis. Instead, when questionable data were observed, additional cross checking was performed to ensure whether the data were acceptable or not for subsequent analysis. Table 1 provides a summary of sources responsible for providing the data.

Table 1: Types and sources of data used in the analysis.

Type of Data	Source
Meteorology – Precipitation, temperature, snow accumulation, and evapotranspiration	National Weather Service
Physical characteristics – Topography, hydrogeology	US Forest Service, USGS, and individual mine companies
Surface and ground water – Outside the mine permitted area	Division of Oil, Gas, & Mining, USGS, US Bureau of Reclamation
Surface and groundwater – Mine permitted area	Individual mine company data obtained via the APPX data base

The different types of monitoring locations include, stream stations, ground water monitoring wells, precipitation, evapotranspiration (ET), springs, mine interceptions, and mine discharges. The water quality parameters used in this study were pH, total suspended solids (TSS), total dissolved solids (TDS), dissolved oxygen (DO), specific conductance, chromium, cadmium, mercury, arsenic, lead, zinc, iron, sulfate, nitrate, orthophosphate,

manganese, magnesium, calcium, bicarbonates, total alkalinity, and total hardness. However, it should be noted that all of these parameters were not available at each station and only the available parameters will be presented and discussed.

The maximum contaminant level (MCL) of a chemical is the maximum permissible dissolved concentration to maintain drinking water quality standards and usually stipulated by the US Environmental Protection Agency (US EPA). However, MCL values are not available for all chemicals. In such cases, the discussion will focus on monitoring locations with high concentrations.

3.4.2 Selection of Monitoring Stations

As discussed earlier, there are many monitoring stations available for water quality information from various sources. However, upon careful analysis, it was found that only a small number of stations can be used or were needed in the final analysis. It should be noted that sufficient data over a relatively long period of time are needed for a meaningful statistical analysis. The selection procedure will be discussed in the next paragraph.

The total number of stream, spring, mine interception, mine discharge, and ground water stations available within the White Oak Mine were 11, 8, 0, 6, and 1, respectively; and these do not include USGS stations. Of these stations, four stream stations were dropped due to lack of data and poor locations with respect to the study area. Of the springs, two springs were not included due to the limited hydrogeological influence to mining activities based on the elevations and locations. Two more springs were not selected as these were located in the Huntington Watershed. Unfortunately, all mine discharge stations were dropped as these stations did not contain any flow data. Therefore, the final analysis included 7 stream stations, 3 springs, and 1 ground water well. The locations of these monitoring stations are given in Figure 13.

Skyline Mine data showed the presence of 19 stream, 15 spring, 1 seep, 0 mine interception, 6 mine discharge, and 7 ground water stations. Of the stream stations, 5 did not have data

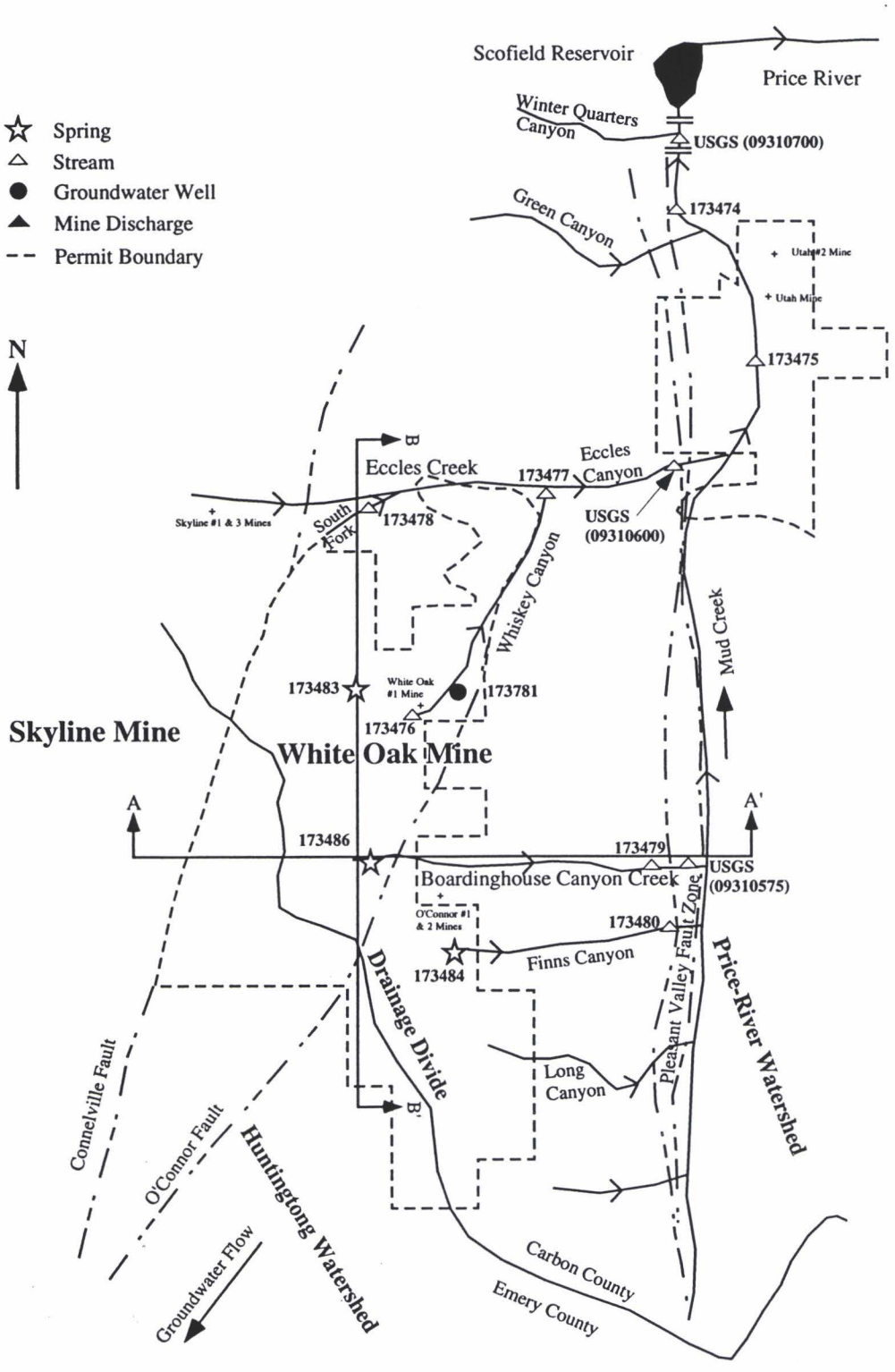


Figure 13. Locations of the monitoring stations in the White Oak Mine selected for the final analysis.

and 7 stations were located in the Huntington Watershed or located closer to other selected stations. Therefore, the final analysis included 7 stream monitoring stations. Most springs were located in the Huntington Watershed and at elevations that do not provide a significant contribution to the overall analysis. The final selection included 4 springs and 1 seep. Four mine discharge stations were selected and one was disregarded due to the lack of information. Of these four mine discharge stations, two stations were discharging to sedimentation ponds located near the portal and loadout areas. The remaining two discharge locations corresponded to UPDES stations discharging to Eccles Creek. One ground water location was selected as the others were located in the Huntington Watershed. The locations of these monitoring stations are given in Figure 14.

Starpoint Mine contained 12 stream, 33 spring, 4 mine interception, 1 mine discharge, and 14 ground water monitoring stations. Of the stream stations, 3 stations were selected as the others were either located in the Huntington Watershed or were not situated at critical locations to provide a significant contribution. Also, the selected stations were found to be adequate without deteriorating the quality of the results. In selecting the springs, the preference order was Starpoint, Blackhawk, Castlegate, Price River, and North Horn Formations, so that the direct impact of coal mining could be assessed. Six springs were selected for the final analysis as the others were either located in the Huntington Watershed or did not have sufficient data. All four mine interception stations were selected and the only mine discharge station was ignored due to reported zero flow data. Most ground water stations were ignored as there were no reported data and some were located in the Huntington Watershed. The selected number of ground water stations was three. The locations of these monitoring stations are given in Figure 15.

For the final analysis, 17 stream, 13 spring, one seep, 4 mine interception, 4 mine discharge, and 5 ground water stations were selected from the APPX data base.

In addition, the USGS data base was also studied carefully and of the stations listed, 22 stations reported at least 9 data points. However, the majority of the stations from this selection were located either too far east or west of the mining areas of interest or contained

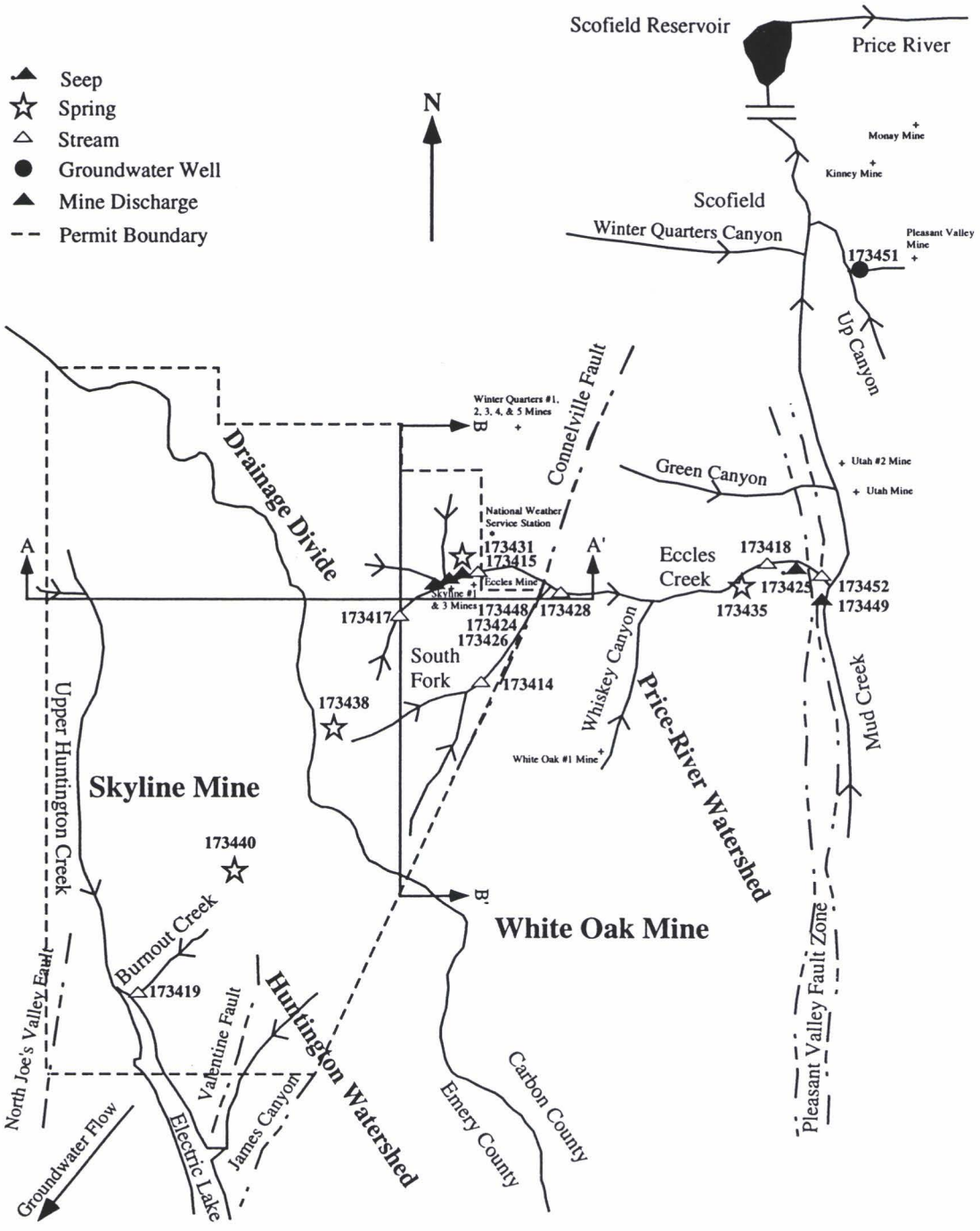


Figure 14. Locations of the monitoring stations in the Skyline Mine selected for the final analysis.

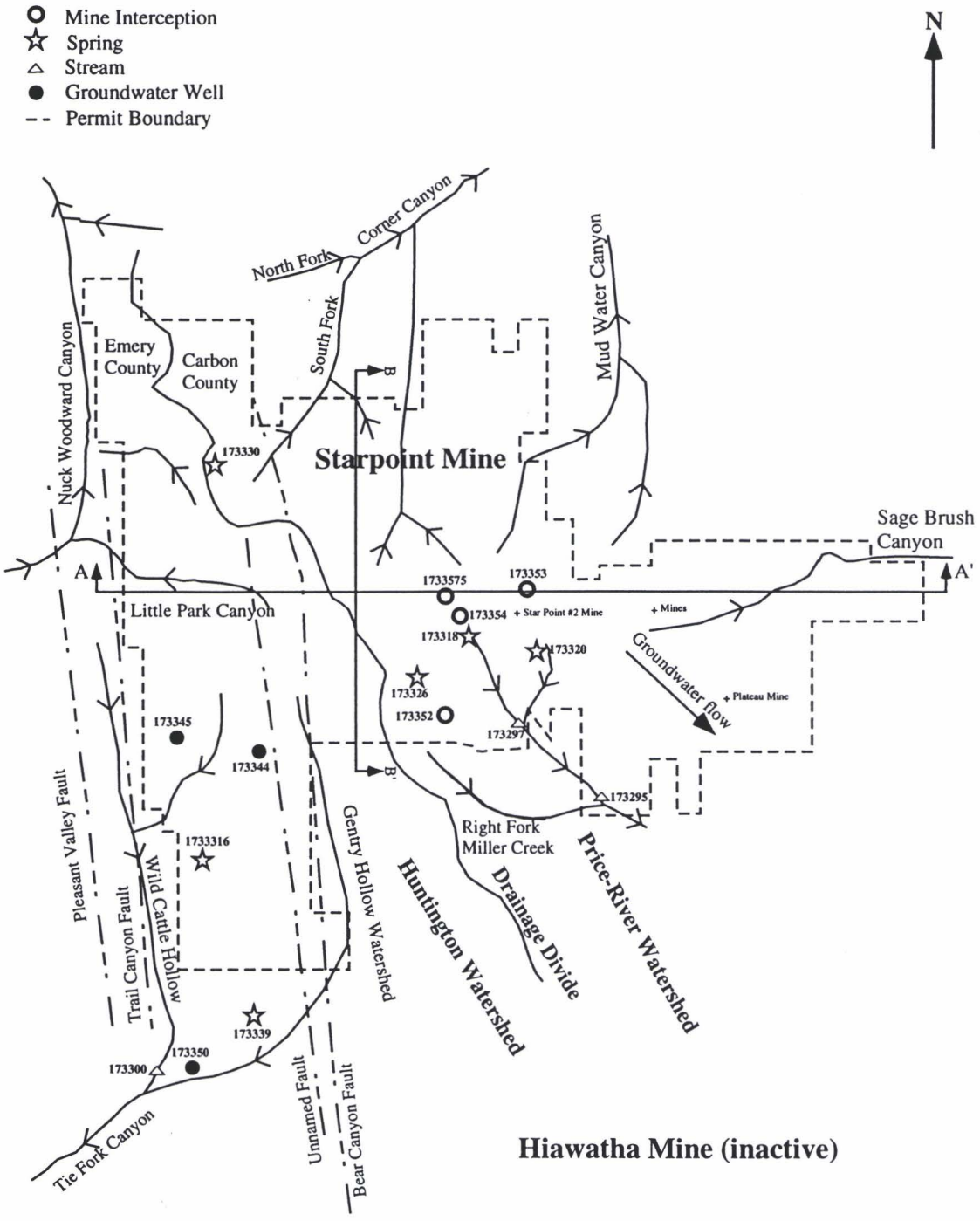


Figure 15. Locations of the monitoring stations in the Starpoint Mine selected for the final analysis.

minimal data. At some stations, flow data were not available or the only data available were for specific conductance. Therefore, three stations were selected from the USGS data base that could provide some contribution to the study.

As mentioned earlier, there were no reported data or monitoring stations from other federal, state, and local agencies including the EWC. A summary of all selected monitoring stations is given in Table 2.

The APPX data base of the DOGM is currently being updated on a daily basis. The data reported in this study were the data available at the time of retrieval and analysis. However, it may be possible that additional data are available at the time of preparation of this report.

Table 2: Description of monitoring stations selected in the analysis of coal mining areas of Price River Watershed.

Station	Code	Category	Name and Description
		White Oak Mine	
173474	VC-1	Stream	Mud Creek; below Utah # 2 Mine
173475	VC-2	Stream	Mud Creek; above Utah # 2 Mine
173476	VC-4	Stream	Whiskey Canyon; above White Oak Mine
173477	VC-5	Stream	Whiskey Canyon; below White Oak Mine
173478	VC-10	Stream	South Fork; above Eccles Creek
173479	VC-11	Stream	Boardinghouse Canyon; above spring houses
173480	VC-12	Stream	Finns Canyon; above Mud Creek
173483	S 25-13	Spring	Price River Watershed; approximate elevation 9360 feet and in North Horn Formation
173484	S 31-13	Spring	Price River Watershed; approximate elevation 9480 feet and in North Horn Formation
173486	S 36-17	Spring	Price River Watershed; approximate elevation 9043 feet and in North Horn Formation
173781	W19-1	Ground Water	In Whiskey Canyon and used in the mine as a culinary source
		Skyline Mine	
173414	CS-1	Stream	Upper South Fork of Eccles Creek
173415	CS-2	Stream	Eccles Creek at USFS boundary
173417	CS-4	Stream	Upper Left Fork of Eccles Creek
173418	CS-6	Stream	Eccles Creek; near USGS gaging station
173419	CS-7	Stream	Burnout Creek; at confluence with Electric Lake
173424	CS-12	Mine Discharge	Discharge from # 3 Mine to sedimentation pond 173448
173425	CS-13	Seep	Seep located near loadout
173426	CS-14	Mine Discharge	Discharge from # 1 Mine to sedimentation pond 173448
173428	VC-6	Stream	Eccles Creek; above confluence with South Fork
173431	S 13-2	Spring	Price River Watershed; approx. elevation 8800 feet and in Blackhawk Formation
173435	S 17-2	Spring	Price River Watershed; approx. elevation 8080 feet and in Blackhawk Formation
173438	S 23-4	Spring	Price River Watershed; approx. elevation 9280 feet and in Blackhawk Formation
173440	S 26-13	Spring	Huntington Watershed; approx. elevation 9440 feet and in Blackhawk Formation
173448	UPDES 001	UPDES	Portal area discharge to Eccles Creek
173449	UPDES 002	UPDES	Loadout area discharge to Eccles Creek
173451	W 92-91-03	Ground Water	Price River Watershed
173452	VC-9	Stream	Eccles Creek; above confluence with Mud Creek

Starpoint Mine			
173295	ST-1	Stream	North Fork of Right Fork Miller Creek; above confluence
173297	M-8	Stream	North Fork of Right Fork Miller Creek; at permit boundary
173300	34-1	Stream	Wild Cattle Hollow; above confluence with Gentry Hollow
173316	458	Spring	Within Wild Cattle Hollow Ridge; approx. elevation 9440 feet and in Price River Formation
173318	492	Spring	North Fork of Right Fork Miller Creek headwaters; approx. elevation 9440 feet and in Castlegate Formation
173320	500	Spring	East drainage of North Fork of Right Fork Miller Creek; approx. elevation 9480 feet and in Price River Formation
173326	753	Spring	East side of Hoag Ridge; approx. elevation 10,060 feet and in North Horn Formation
173330	CVS-7	Spring	Castle Valley Ridge-drains into South Fork of Corner Canyon; approx. elevation 9560 feet and in Blackhawk Formation
173339	85-26-1	Spring	South end Gentry Ridge and south of mine permit boundary; approx. elevation 9360 feet and in North Horn Formation
173344	P92-01C-WD	Ground Water	Within mine area; below Gentry Ridge
173345	P92-02-WD	Ground Water	Within mine area; below Gentry Ridge; on west edge of boundary
173350	86-35-2-3	Ground Water	Gentry Hollow above confluence with Wild Cattle Hollow
173352	9 L 12	Mine Interception	Ninth Left 12
173353	1 W 4	Mine Interception	First West 4
173354	Gentry Ridge	Mine Interception	Gentry Ridge
173575	1 W 6	Mine Interception	First West 6

USGS			
Station	**Latitude**	**Longitude**	**Type and Description**
09310575	111° 09' 18"	39° 39' 00"	Stream – Boardinghouse Canyon at mouth of Scofield
09310600	111° 09' 38"	39° 41' 07"	Stream – Eccles Creek near Scofield
09310700	111° 09' 38"	39° 43' 18"	Stream – Mud Creek below Winter Quarters Canyon at Scofield

3.4.3 Statistical Analysis

The statistical analysis was performed using the procedures described by Gilbert (1987) and Kendall (1975), and also described further by Kaluarachchi and Abdin (1998a) in Part I of this document series. The output from the analysis provided seasonal means, seasonal trends, and correlations. The statistical analysis requires the identification of three seasons to compute the seasonal means. Based on the normal weather pattern in the study area, Seasons 1 (S1), 2 (S2), and 3 (S3) correspond to April-July, August-October, and November-March, respectively.

In interpreting the results, emphasis should be given to both the time-series plots and the statistics computed from the analysis. If a seasonal trend is computed with poor probability of trend, then the validity of the computed seasonal trend is limited at the expected confidence interval of 95%. Also in cases where there are limited data or missing data to represent accurate seasonal behaviors, the trend analysis may produce a poor overall trend.

In addition, there is a travel time for water in surface or ground water systems. In the absence of detailed tracer studies, the actual travel times in the subsurface are unknown. However, due to the relatively low hydraulic conductivity in the upper formations and slower velocity fields in porous media, the travel times in the subsurface can be substantial. On the other hand, the travel times in surface water, especially during peak periods, can be high. Since the data for flow and chemical concentrations are discussed over time periods of at least ten years, the impact of a chemical on surface water quality can be transmitted relatively fast. Therefore, the travel times between surface water monitoring stations in this study can be assumed small compared to the overall time period of analysis.

Finally, the concentrations of various chemical parameters are given here as total concentrations rather than as dissolved and/or solid phase concentrations. Although MCL is defined with respect to the dissolved phase, we have used MCL with the total concentrations to assess the qualitative difference between the values. The reason for this approach is that there are no established MCL values for total concentrations and on the other hand, total

mass loading carried by water is based on the total concentration rather than on the dissolved concentration. Therefore, assessments made here with any reference to MCL will be conservative and can be considered as the upper bound for future corrective measures.

4.0 RESULTS AND DISCUSSION

As shown in Figures 13, 14, and 15, White Oak and Skyline Mines are located relatively close to each other whereas the Starpoint Mine is located further southeast. Therefore, the results and discussion will first address the White Oak and Skyline Mines together and will include Eccles Creek, Whiskey Canyon, South Fork, upstream of Mud Creek, and finally the discharge from Scofield Reservoir to Price River. Second, we will address the data obtained from the Starpoint Mine.

4.1 Precipitation and Evapotranspiration

There are four National Weather Service Stations available in the Price River Watershed. These stations are located at the City of Scofield, at the Scofield Dam, near the upper right boundary of the Skyline Mine, and at Mammoth. The last station is at a different watershed and therefore, disregarded in the analysis. The weather stations at the City of Scofield and at the Scofield Dam are far away from most monitoring stations of White Oak and Skyline Mines chosen for the final analysis. Since the weather station located near the Skyline Mine boundary is at a central location to these monitoring stations, this station was chosen to study the precipitation and evapotranspiration data. Starpoint Mine is located further southeast from White Oak and Skyline Mines, but it can be assumed that the data from this weather station are representative of conditions at the Starpoint Mine permitted area.

The average annual precipitation in the Price River Watershed ranges from about 8 inches in the southern part to more than 30 inches in the extreme northwestern part (U.S. Weather Bureau, 1963). Above 8,000 feet, the climate is sub-humid. Precipitation generally is less above 7,000 feet along the northeastern part of the watershed than it is at similar altitudes in the western parts of the watershed. On the average, about 50% of the total precipitation falls on the upstream 30% of the area. Approximately, 70% of the precipitation falls on areas

with altitudes greater than 6,000 feet, and 65% of this total precipitation is snow that occurs during October to April (Mundroff, 1972). The majority of the precipitation that falls on lower altitudes comes as thunderstorms during the late summer months. The mean annual air temperature ranges from about 35^0 F at higher altitudes to about 50^0 F at altitudes below 6,000 feet. The normal annual free-water surface evaporation is between 35 and 45 inches (Farnsworth et al., 1982).

Figures 16a and 16b show the time-series plots of average monthly precipitation and evapotranspiration (ET) from July 1984 to September 1997. Since most monitoring periods where water flow and quality data are available fall within this time frame, these precipitation and ET data can be directly used in data interpretation. Due to seasonal variations, ET data showed a cyclic pattern with values varying between 0.5 and 6 inches. However, the precipitation data show a random behavior due to changing weather patterns associated with each year. The average monthly precipitation varied from 0.5 inches to 3 inches and in some years, the peak values were as high as 9 inches. These high values in some years, such as 1985 to 1986, or 1996 to 1997, indicate that recharge to the area is significant; and this observation should be reflected in stream discharge data.

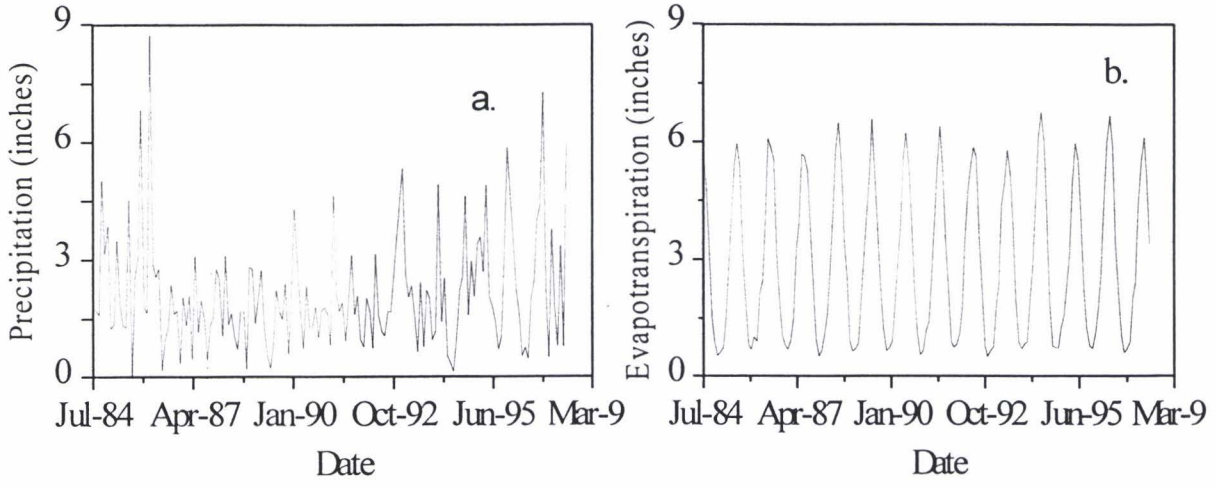


Figure 16: Time-series distributions of (a) precipitation and (b) evapotranspiration.

The statistical analysis indicated that mean monthly precipitation of Seasons 1, 2, and 3 was 1.7, 1.8 , and 2.7 inches, respectively, with a range of 0 to 8.7 inches. The same values for ET were 4.7, 3.7, and 1 inches with a range of 0.5 to 6.8 inches. In addition, the precipitation increased at 0.035 inch per year with 83% probability and ET increased 0.01 inch per year with 65% probability. Due to the poor probability of trend of ET, this trend value can be disregarded. These results indicate that during spring to early summer months, ET exceeded the precipitation by more than three-fold indicating a net water loss from the watershed. However, during the winter months, ET was almost one-third of the precipitation indicating good recharge to the watershed.

4.2 White Oak and Skyline Mines

4.2.1 Background Concentrations

In order to study the changes and impacts on water quality due to a given parameter, it is important to know the actual concentration changes, MCL, and the background concentration. The background concentration is defined as the natural concentration of a parameter existing in the area of interest without the impact of man-made activities. As mentioned earlier, the results will be discussed in two sections; first, White Oak and Skyline Mines together, and second, Starpoint Mine. In order to determine the background concentrations, it is important to use monitoring station(s) that are not affected by man-made activities or land uses. Therefore, the ideal locations for background concentrations are springs located at higher elevations and, preferably, upstream of important land uses such as coal mining operations. The best available location to determine background concentrations for White Oak and Skyline Mines was judged to be Spring 173484 which is located around 9,480 feet of elevation in the North Horn Formation. In the case of the Skyline Mine, Spring 173440 which is located at 9440 feet elevation in the Blackhawk Formation was considered the best. Since the data from both mine areas will be jointly analyzed and discussed in this report as these are closely located, it was decided to use the range of values reported by these two representative springs as the background concentrations. Since, TDS, iron,

manganese, sulfate, and lead were the chemicals of concern (COC), the background concentrations of these parameters are given in Table 3.

Table 3: Range of background concentrations and MCLs of selected parameters used in the analysis of data from the White Oak and Skylines Mines. The data for the Huntington Watershed were from Kaluarachchi and Abdin (1998b).

Parameter	Background Concentration (mg/L)	Background Concentration from Huntington Watershed (mg/L)	MCL (mg/L)
TSS	20-747	92	-
TDS	275-345	426	500
Iron	0.27-0.52	1.1	0.3
Sulfate	62-114	90	250
Lead	0.1	0.05	0.05
Manganese	0.02-0.1	0.06	0.05

In addition, TSS concentrations were high in many areas of this watershed and since it has no established MCL, the background value of TSS was essential. The TSS from previous springs indicated that the value may be between 8 and 11 mg/L. However, this range seems too small and there is a possibility that streams may contain higher TSS values due to bed erosion during peak flow times. Therefore, existing concentrations of TSS at different stream monitoring stations were closely studied. From this study, it was found that at monitoring locations far away from mining activities, the TSS values may represent background concentrations. Finally, the data from stream stations 173414, 173417, 173419, 173478, 173479, and 173480 produced a background range of 20 to 747 mg/L.

Table 3 also shows the background values used in the analysis of Huntington Watershed data and discussed in Kaluarachchi and Abdin (1998b). The data from the Huntington Watershed show that TSS, sulfate, and lead values are more conservative whereas TDS and

iron have higher background values. However, the present study used the background values applicable to the Price River Watershed.

It should be noted here that these background values may not necessarily represent true background values as concentrations even under perfect natural conditions can change over time and space, especially in a large watershed such as the Price River. Therefore, these concentrations should be viewed and used as guidelines only.

4.2.2 Whiskey Canyon

Stream Flow

Water in the White Oak Mine is collected primarily through Eccles Creek and Pleasant Valley Creek or Mud Creek (Figure 13). Both Eccles and Mud Creeks are perennial and so these are constant sources of flow to Scofield Reservoir. Most of the flow from White Oak Mine is carried through Whiskey Canyon and on to Eccles Creek, which then flows east towards Mud Creek.

The most upstream stream monitoring station in Whiskey Canyon is 173476 and the most downstream station is 173477 which is located at the junction with Eccles Creek (Figure 13). Figure 17a shows the flow at the upstream station, 173476, from 1977 to 1995 obtained from the White Oak Mine. The data show seasonally high flow from late 1970's to mid 1980's followed by slightly decreased peak values. Table 4 shows that the mean of Season 1, which is spring to early summer time, is much higher than Season 2, and Season 3 showed a zero mean for the entire period. The flow varied from 0 to 1 cfs during this period. Table A1 in Appendix A indicates a zero trend of flow. However, the probability of this trend is 42% indicating low certainty due to limitations of data. Also, correlations of flow with precipitation or ET are poor too.

Figure 17b shows the flow in Whiskey Canyon just before the Eccles Creek intersection. Compared to the upstream location 173476, the data clearly show almost three times higher flow in the downstream station over the same period and both stations followed a similar

Table 4. Summary water quality data at Stream Station 173476 of Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	68	03/17/77-10/18/95	0	1	0.1212	0.0051	0	-	-
pH	**48**	**06/14/78-10/18/95**	**6.3**	**8.7**	**7.2**	**7.9**	**-**	**6.5-8.5**	**2**
TSS	**47**	**06/14/78-10/18/95**	**1**	**15940**	**36.4**	**1197.5**	**-**	**-**	**-**
TDS	**48**	**06/14/78-10/18/95**	**40**	**600**	**115**	**237.6**	**-**	**500**	**1**
Dissolved Oxygen	29	06/14/87-10/18/95	6.3	12.4	9.2	8.5	-	-	-
S. Cond. (µmhos/cm)	28	06/14/78-10/18/95	68	920	146.5	341	-	-	-
Chromium	4	10/13/82-09/10/91	0.001	0.026	0.01	0.0123	-	0.05	0
Cadmium	15	06/14/78-10/18/95	0.001	0.01	0.0074	0.0049	-	0.01	0
Mercury	9	06/14/78-09/10/91	0.0002	0.002	0.0002	0.0006	-	0.002	0
Arsenic	11	06/14/78-10/18/95	0.001	0.04	0.0106	0.0072	-	0.05	0
Lead	16	06/14/78-10/18/95	0.001	0.021	0.0079	0.0081	-	0.05	0
Zinc	16	06/14/78-10/18/95	0.001	0.215	0.0374	0.0344	-	5	0
Iron	**34**	**06/14/78-10/18/95**	**0.02**	**22.5**	**0.85**	**2.4**	**-**	**0.3**	**23**
Sulfate	48	06/14/78-10/18/95	0.1	304	11.3	36.7	-	250	1
Nitrate	15	06/14/78-10/18/95	0.01	0.353	0.1519	0.0451	-	10	0
Orthophosphate	6	06/14/78-05/19/94	0.01	3	0.0467	1	-	-	-
Manganese	**34**	**06/14/78-10/18/95**	**0.001**	**6.6**	**0.0213**	**0.5745**	**-**	**0.05**	**4**
Magnesium	48	06/14/78-10/18/95	1.9	96	6	16.4	-	-	-
Calcium	48	06/14/78-10/18/95	11.2	72	25.7	50.7	-	-	-
Bicarbonate as HCO_3^-	48	06/14/78-10/18/95	3.3	273.3	105.7	207.6	-	-	-
Total Alkalinity as $CaCO_3$	10	06/20/79-06/27/86	2.7	202	75.3	142.7	-	-	-
Total Hardness as $CaCO_3$	16	09/26/84-10/18/95	8.1	199	77.8	186.2	-	-	-

pattern of flow. Table 5 shows a three-times higher seasonal mean for Season 1 compared to Season 2 with flow varying 0 to 3.7 cfs. Table A2 in Appendix A shows that flow decreased at 0.04 cfs per year with 100% probability. However, the correlations between flow and precipitation or ET are poor. A possible reason for these poor correlations may be the inadequate spread of the data and/or there are other dominant surface and subsurface features that can influence these parameters. It is obvious that flow in the downstream station, 173477, should be higher as it collects runoff and base flow from upstream to downstream. It is possible that the majority of the base flow to Whiskey Canyon may be occurring through nearby faults, such as the O'Connor Fault (White Oak Mine Permit Documentation, 1995). In summary, the data show that flow to Eccles Creek from Whiskey Canyon decreased from 1977 to 1995 with high probability.

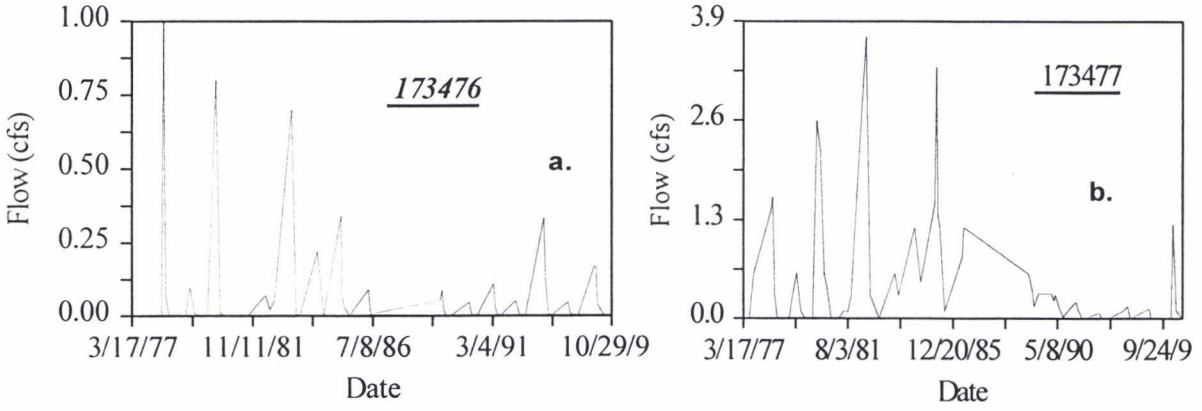


Figure 17: Time-series distributions of flow at stations (a) 173477 and (b) 173476.

Spring Flow

Figure 18 shows the time-series plot of flow in Spring 173483 located upstream of Whiskey Canyon. Spring 173483 is located at 9,360 feet elevation in the North Horn and Price River Formations. The data show relatively high flows from 1982 to 1984 and from 1991 to 1993. Table 6 shows that the mean flow of Season 1 is higher than Season 2 due to snowmelt and associated recharge, and almost dry conditions during the winter period. The flow varied from 0 to 0.1337 cfs at this spring. Table A3 in Appendix A indicates a negligible trend in flow from 1980 through 1995 with a probability of 97.2%. However, the correlations

Table 5. Summary water quality data at Stream Station 173477 of Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	72	03/17/77-10/18/95	0	3.7	0.6542	0.2063	0	-	-
pH	**59**	**08/25/77-10/18/95**	**6.4**	**9.2**	**7.7**	**8.1**	**7.8**	**6.5-8.5**	**9**
TSS	**58**	**08/25/77-10/18/95**	**1**	**17030**	**630.3**	**1081.6**	**1952.5**	**-**	**-**
TDS	**58**	**08/25/77-10/18/95**	**138**	**4000**	**495.1**	**367.2**	**377**	**500**	**12**
Dissolved Oxygen	33	08/25/77-10/18/95	7.4	12.8	9.6	9.6	-	-	-
S. Cond. (µmhos/cm)	35	08/25/77-10/18/95	208	1326	449.2	535.6	600	-	-
Chromium	7	08/25/80-05/30/91	0.001	0.01	0.01	0.0028	-	0.05	0
Cadmium	19	08/25/77-10/18/95	0.001	0.016	0.0077	0.0041	-	0.01	1
Mercury	15	08/25/77-05/30/91	0.0002	0.002	0.0002	0.0004	-	0.002	0
Arsenic	16	08/25/77-10/18/95	0.001	0.025	0.0066	0.0036	-	0.05	0
Lead	22	08/25/77-10/18/95	0.001	0.01	0.0064	0.0046	-	0.05	0
Zinc	22	08/25/77-10/18/95	0.001	0.707	0.1289	0.0213	-	5	0
Iron	**42**	**08/25/77-10/18/95**	**0.011**	**88.5**	**8.3**	**1.7**	**44.2**	**0.3**	**29**
Sulfate	59	08/25/77-10/18/95	10	286	87.5	82.4	72.5	250	1
Nitrate	20	08/25/77-10/18/95	0.01	1.1	0.4754	0.077	-	10	0
Orthophosphate	9	08/25/77-10/13/82	0.01	2	0.5408	0.058	-	-	-
Manganese	**43**	**08/25/77-10/18/95**	**0.001**	**7.2**	**0.282**	**0.492**	**0.89**	**0.05**	**18**
Magnesium	59	08/25/77-10/18/95	5.8	60.9	23.8	29.6	22.8	-	-
Calcium	59	08/25/77-10/18/95	32.5	119	62.2	63.5	70	-	-
Bicarbonate as HCO_3^-	59	08/25/77-10/18/95	50	349	193	237.7	251.2	-	-
Total Alkalinity as $CaCO_3$	13	08/25/77-06/27/86	116	252.9	166.4	187.9	-	-	-
Total Hardness as $CaCO_3$	16	09/26/84-10/18/95	156	731	332.9	351.2	-	-	-

Table 6. Summary water quality data at Spring 173483 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	42	06/26/80-10/18/95	0	0.1337	0.0292	0.003	-	-	-
pH	**43**	**06/23/80-10/18/95**	**6.1**	**8.8**	**7.4**	**7.6**	**-**	**6.5-8.5**	**1**
TSS	3	06/26/80-10/08/80	12	42	12	29.5	-	-	-
TDS	43	06/26/80-10/18/95	41	290	115.6	172.6	-	500	0
S. Cond. (µmhos/cm)	43	06/26/80-10/18/95	64	477	160	276.8	-	-	-
Chromium	7	08/26/80-05/26/92	0.001	0.01	0.01	0.0046	-	0.05	0
Cadmium	16	08/26/80-10/18/95	0.001	0.01	0.01	0.0059	-	0.01	0
Mercury	5	08/26/80-05/26/92	0.0002	0.0005	0.0005	0.0002	-	0.002	0
Arsenic	11	08/26/80-10/18/95	0.001	0.05	0.0333	0.0105	-	0.05	0
Lead	**16**	**08/26/80-10/18/95**	**0.001**	**0.12**	**0.0117**	**0.0174**	**-**	**0.05**	**1**
Zinc	16	08/26/80-10/18/95	0.01	0.218	0.0473	0.0243	-	5	0
Iron	**18**	**06/26/80-10/18/95**	**0.025**	**4.3**	**1.3**	**0.6373**	**-**	**0.3**	**10**
Sulfate	42	06/26/80-10/18/95	0.1	55.4	11.1	13.6	-	250	0
Nitrate	16	08/26/80-10/18/95	0.01	0.52	0.199	0.2482	-	10	0
Orthophosphate	10	08/26/80-05/19/94	0.01	0.081	0.0468	0.051	-	-	-
Manganese	**31**	**06/26/80-10/18/95**	**0.001**	**0.146**	**0.0298**	**0.031**	**-**	**0.05**	**5**
Magnesium	43	06/26/80-10/18/95	1.28	32.1	6.3	9.1	-	-	-
Calcium	43	06/26/80-10/18/95	9.2	533.9	57.3	44.8	-	-	-
Bicarbonate as HCO_3^-	43	06/26/80-10/18/95	12.4	442	113	170.5	-	-	-
Total Alkalinity as $CaCO_3$	8	08/26/80-06/28/86	10.2	198	79.2	119.5	-	-	-
Total Hardness as $CaCO_3$	19	09/26/84-10/18/95	0.5	189	51.7	155.1	-	-	-

between flow and precipitation or ET remained poor. A possible reason for these poor results may be that there is a substantial travel time for subsurface water to flow from the recharge point at the surface to the local saturated zone. This travel time is not reflected in the analysis and, therefore, the correlations may be poor. Since the spring is located at a higher elevation than that of coal mining operations, it can be assumed that this spring is not affected by coal mining. Previous studies have determined (Vaughn Hansen Associates, 1985) that springs in this region are formed due to localized saturated zones rather than through long and well-connected networks that are fault related. In fact, it has been found that the subsurface, mainly the sandstone, is discontinuous and there is no established network of water flow to form large-scale springs. Spring flows have been relatively small even during the summer months and sometimes can change by one order of magnitude over the same year (Vaughn Hansen Associates, 1985). These conclusions are further substantiated by the data from this spring.

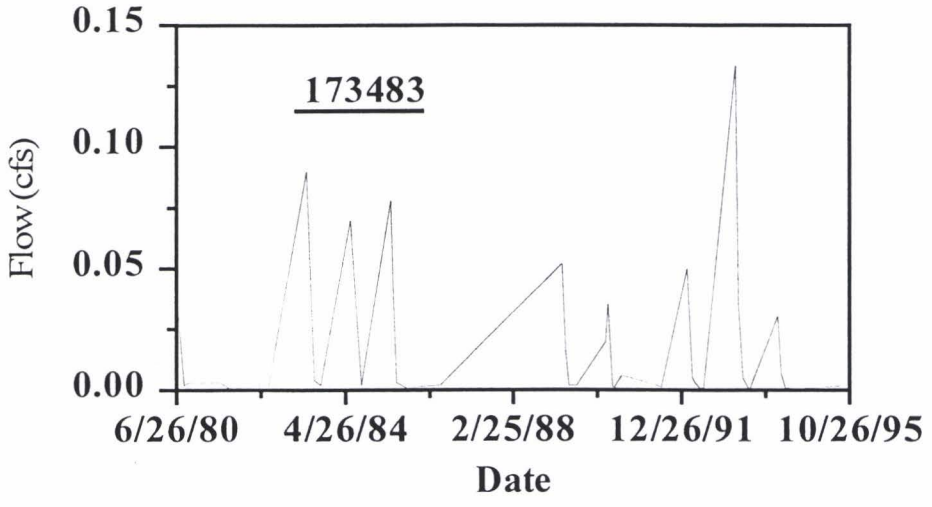


Figure 18: Time-series distribution of flow at Spring 173483.

Water Quality of Whiskey Canyon

Table 4 shows the summary water quality data at the upstream station of Whiskey Canyon, 173476, where it is seen that TDS, iron, and manganese are the COC. In addition, pH exceeded the acceptable range of 6.5-8.5 with a minimum of 6.3 and a maximum of 8.7. However, these values may not necessarily reflect any serious water quality deterioration or

acid mine drainage problems. Although TDS was high, it exceeded the MCL only once in early the 1980's. On the other hand, iron exceeded the MCL 23 times and manganese exceeded the MCL 4 times. The time-series plot of iron concentration at this station is shown in Figure 19. The concentrations of these COC are much higher than the background values given in Table 3, especially for iron and manganese. The peak concentrations of TSS and iron were 15,940 mg/L and 22.5 mg/L, respectively. Table A1 in Appendix A indicates that there are decreasing seasonal trends of concentration for these chemicals, especially for manganese and TSS with good probability. Although, TSS has no established MCL, the data show that the observed concentrations are more than one order of magnitude higher than the background values given in Table 3. Therefore, it can be concluded that upstream locations of Whiskey Canyon showed serious water quality problems between 1978 and 1995 with respect to TSS, iron, and manganese.

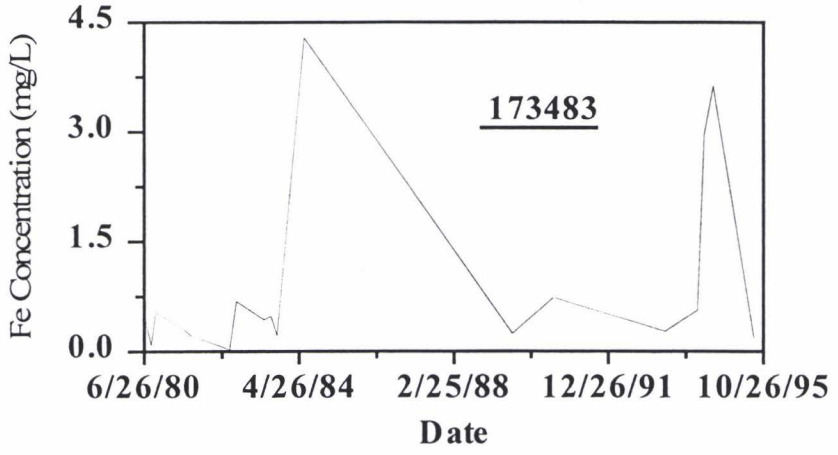


Figure 19: Time-series distribution of iron at Station 173483.

Table 5 shows the summary water quality data of the downstream location of Whiskey Canyon, 174477. The data indicate higher water quality deterioration than at the upstream station discussed earlier. At this station, TDS, iron, and manganese exceeded the MCL 12, 29, and 18 times, respectively, during the period of 1977 to 1995. Figures 20a through 20c show the time-series plots of TDS, iron, and manganese concentrations. High TDS concentrations occurred in 1986 whereas high iron concentrations occurred in 1978 and 1983. Similarly, peak manganese concentrations occurred in 1979, 1982, 1986, and 1993.

The reported concentrations of these COC plus TSS are more than one order of magnitude higher than the background values reported in Table 3. For example, maximum TSS, TDS, iron, and manganese concentrations were 17,030, 4000, 88.5, and 7.2 mg/L, respectively. Table A2 in Appendix A indicates decreasing seasonal trends of TSS, iron, and manganese concentrations with only TSS showing good probability. However, TDS showed an alarming increasing seasonal trend with excellent probability.

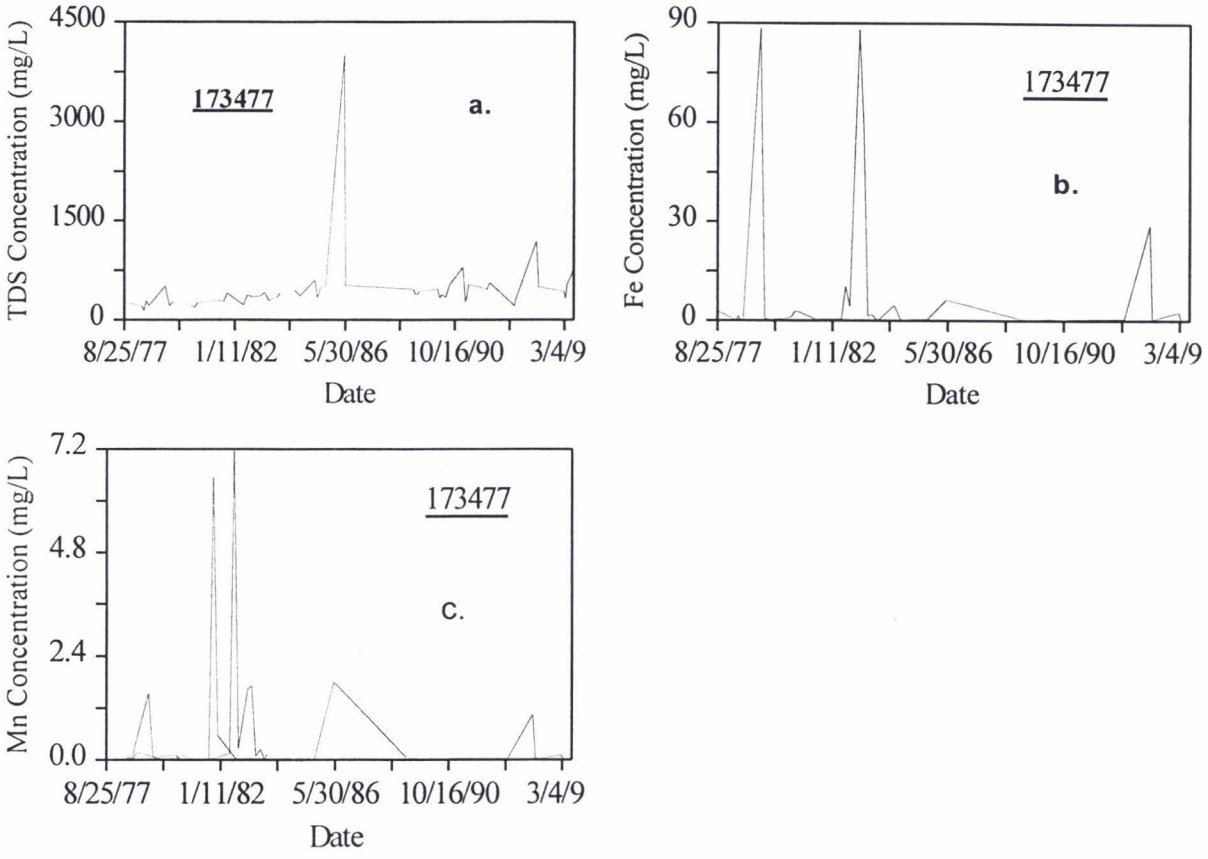


Figure 20: Time-series distributions of (a) TDS, (b) iron, and (c) manganese at Station 173477.

These results clearly indicate serious water quality problems in Whiskey Canyon with respect to TSS, TDS, iron, and manganese from 1978 to 1995, and the problems became worse towards the downstream location. The dissolved oxygen concentrations along the entire canyon remained sufficiently high indicating prevailing aerobic conditions and no presence of biodegradable organics. The sources responsible for these water quality

problems cannot be identified, as base flow or surface runoff have not been quantified or analyzed for water quality. Therefore, it is safe to conclude that some of these recharging mechanisms such as runoff and base flow may be responsible for water quality changes in conjunction with existing land use practices.

Water Quality of Spring

Table 6 shows the summary water quality data at Spring 173483. The data show the presence of lead, iron, and manganese as the COC. Of these chemicals, lead exceeded the MCL once whereas iron and manganese exceeded the MCL 10 and 5 times, respectively. Figures 21a and 21b show the time-series plots of iron and manganese concentrations, respectively.

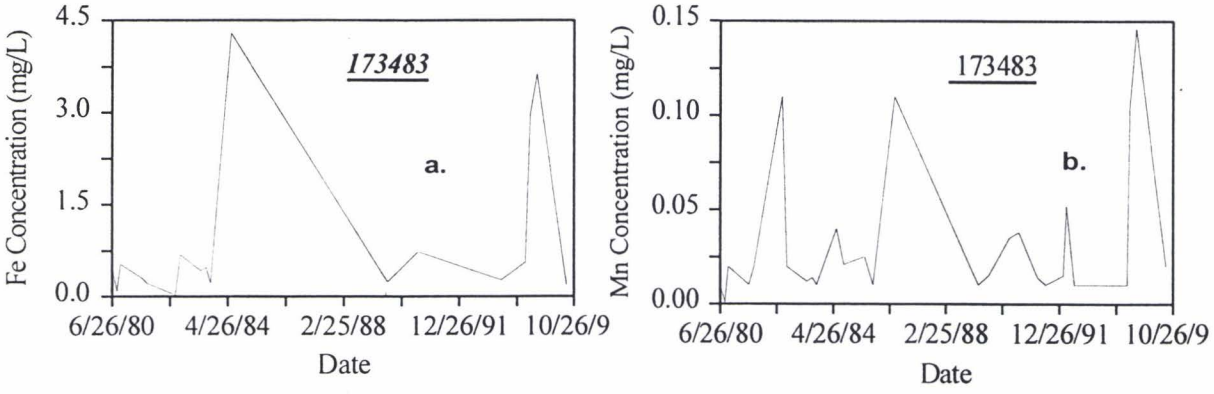


Figure 21: Time-series distributions of iron and manganese at Station 173483.

Using the background concentrations given in Table 3, it can be concluded that manganese concentrations are slightly higher than the background value whereas the iron concentration is almost 8 times higher than the background value. Table A3 in Appendix A shows an increasing seasonal trend of iron with modest probability. This spring is located at 9,360 feet elevation in the Price River and North Horn Formations. Therefore, the impacts of coal mining operations may be limited. There were no data available on dissolved oxygen at this spring. Although water quality concerns in this spring are not as serious as in Whiskey Canyon, the data show some concerns with respect to iron. It should be noted here that the

exact mechanisms and practices responsible for these water quality changes cannot be identified due to the lack of information, such as the results from a tracer study, which can provide hydraulic connectivity between different formations and sources. However, it can be concluded that natural geochemical reactions between water and formation materials of locally saturated zones may be partly responsible for changes in water quality.

Quality of Ground Water

Previous studies have mentioned that the low permeability of shale prevents substantial recharge to the subsurface (White Oak Mine Permit Documentation, 1995) in this region. Also, it has been mentioned that there is substantial base flow from the Blackhawk-Starpoint aquifer to nearby streams; for example, as much as 64% of the flow in Eccles Creek is due to base flow through the O'Connor Fault and similar amounts to Mud Creek (White Oak Mine Permit Documentation, 1995). Therefore, any restriction to these flows due to mining or any other activity can reduce stream flow substantially, and thereby, reducing the water availability to users.

The only ground water well available for analysis is the Station 173781 which is the culinary water source of White Oak Mine. The summary water quality data of this well are given in Table 7 where it is seen that the number of data points was four. These limited data show iron is the only chemical of concern. However, the concentration exceeded the MCL only three times, and the reported maximum concentration is within the background concentration given in Table 3. There were no data on dissolved oxygen, but it can be assumed that dissolved oxygen may not be a concern. Therefore, based on the limited data available from this ground water well, it can be stated that ground water quality may not be a concern at this location. However, the actual impact can be determined more accurately only if sufficient data from a number of wells are available.

Table 7. Summary water quality data at Ground Water Well 173781 in Whiskey Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	4	12/05/79-07/19/80	0.03	0.13	0.13	-	0.03	-	-
pH	4	12/05/79-07/19/80	7.5	7.6	7.6	-	7.6	6.5-8.5	0
TSS	4	12/05/79-07/19/80	14	70	42	-	17.5	-	-
TDS	4	12/05/79-07/19/80	300	370	365	-	303	500	0
Chromium	4	12/05/79-07/19/80	0.001	0.001	0.001	-	0.001	0.05	0
Cadmium	4	12/05/79-07/19/80	0.001	0.001	0.001	-	0.001	0.01	0
Mercury	4	12/05/79-07/19/80	0.0002	0.0002	0.0002	-	0.0002	0.002	0
Arsenic	2	07/18/80-07/19/80	0.001	0.001	0.001	-	-	0.05	0
Lead	4	12/05/79-07/19/80	0.001	0.001	0.001	-	0.001	0.05	0
Zinc	4	12/05/79-07/19/80	0.015	0.105	0.018	-	0.1045	5	0
Iron	**4**	**12/05/79-07/19/80**	**0.228**	**0.47**	**0.269**	**-**	**0.4675**	**0.3**	**3**
Sulfate	4	12/05/79-07/19/80	24	110	102	-	25	250	0
Nitrate	4	12/05/79-07/19/80	0.24	0.42	0.37	-	0.27	10	0
Manganese	4	12/05/79-07/19/80	0.01	0.022	0.018	-	0.0105	0.05	0
Magnesium	4	12/05/79-07/19/80	19.6	21.1	19.6	-	20.6	-	-
Calcium	4	12/05/79-07/19/80	62.4	76	64.4	-	75.6	-	-
Bicarbonate as HCO_3^-	4	12/05/79-07/19/80	251.3	309.9	259.9	-	307.4	-	-
Total Alkalinity as $CaCO_3$	4	12/05/79-07/19/80	210	254	215	-	252	-	-

4.2.3 South Fork

Stream Flow

Before Whiskey Canyon joins Eccles Creek, South Fork joins Eccles Creek carrying the flow from the upper left corner of the White Oak Mine property boundary (Figure 13). The two stream stations selected for this analysis are Stations 173414 and 173478. Table 8 shows the summary water flow data at the upstream station, and Figure 22a shows the time-series plot of flow. The flow variability at this location was 0.002 to 3.8 cfs between 1981 and 1997. The data show that the means of Seasons 2 and 3 are approximately one-fourth of Season 1 or the spring time flow. Table A4 of Appendix A shows a slightly decreasing seasonal trend of flow from 1981 to 1997 with good probability. The data from the downstream station, 173478, given in Table 9 show much higher flow over the same period than the upstream station with higher differences between the seasons. The flow variability at this station was 0 to 10.2 cfs. Figure 22b shows the time-series plot of flow where it is seen that the flow is relatively high prior to 1987. In the case of the upstream station, the flow remained high until 1992. Table A5 in Appendix A shows a significant decreasing seasonal trend of flow with good probability.

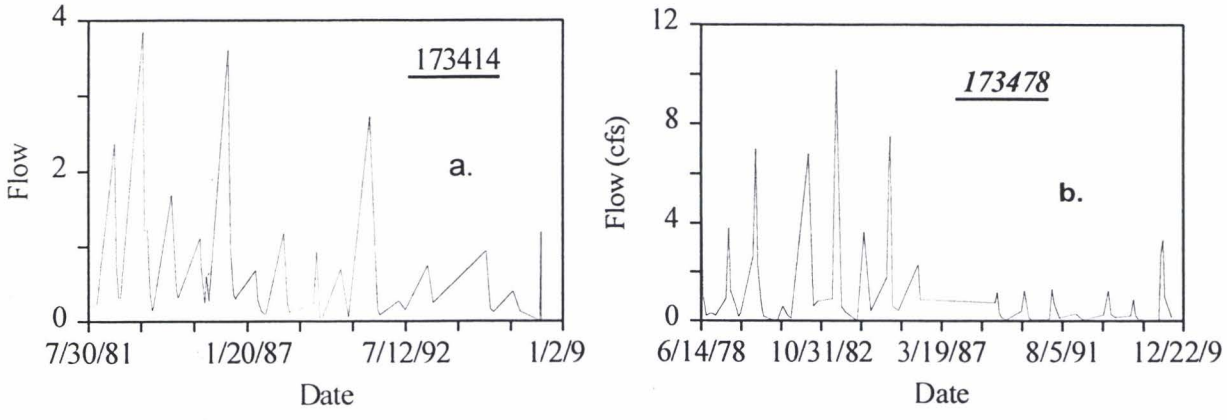


Figure 22: Time-series distributions of flow at Stations 173414 and 173478.

Table 8. Summary water quality data at Stream Station 173414 of upper South Fork of the Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	55	07/30/81-06/24/97	0.002	3.8	1.1	0.2506	0.2049	-	-
pH	**56**	**06/30/82-06/24/97**	**7.3**	**8.6**	**8**	**8**	**7.6**	**6.5-8.5**	**2**
TSS	56	06/30/82-06/24/97	0.1	42	8	4.9	11	-	-
TDS	**54**	**06/30/82-06/23/97**	**160**	**608**	**261**	**370**	**380**	**500**	**6**
Dissolved Oxygen	20	08/20/82-06/23/97	6.2	13.1	8.5	8.6	-	-	-
S. Cond. (µmhos/cm)	55	06/30/82-06/24/97	271	1280	491.5	580.1	529	-	-
Lead	**14**	**08/20/82-09/24/96**	**0.001**	**0.1**	**-**	**0.0176**	**-**	**0.05**	**2**
Zinc	6	08/20/82-08/16/88	0.005	0.058	-	0.0163	-	5	0
Iron	**55**	**06/30/82-06/24/97**	**0**	**0.64**	**0.1604**	**0.0816**	**0.06**	**0.3**	**6**
Sulfate	53	06/30/82-09/24/96	8	275	45.4	94.5	65	250	2
Nitrate	24	08/20/82-06/24/97	0.02	3.65	0.2057	0.5165	-	10	0
Orthophosphate	8	07/11/95-06/24/97	0.01	0.03	0.022	0.0133	-	-	-
Manganese	**56**	**06/30/82-06/24/97**	**0**	**0.133**	**0.0314**	**0.0226**	**0.01**	**0.05**	**9**
Magnesium	38	06/30/82-09/24/96	0.1	50.4	15.3	28.4	25.9	-	-
Calcium	38	06/30/82-09/24/96	52	112	66.7	82.5	81.6	-	-
Bicarbonate as HCO_3^-	56	06/30/82-06/24/97	150	424	242.6	278.3	287.9	-	-
Total Alkalinity as $CaCO_3$	16	07/22/82-09/24/96	199	250.4	216.3	221.7	-	-	-
Total Hardness as $CaCO_3$	7	0616/92-07/11/95	230	486	281.7	467.5	-	-	-

Table 9. Summary water quality data at Stream Station 173478 of South Fork in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	76	06/14/78-10/18/95	0	10.2	1.9	0.2993	0.1599	-	-
pH	**76**	**06/14/78-10/18/95**	**5.8**	**9.2**	**7.7**	**7.8**	**7.7**	**6.5-8.5**	**5**
TSS	75	06/14/78-10/18/95	0.25	133	23.7	16.8	15.9	-	-
TDS	**77**	**06/14/78-10/18/95**	**139**	**721**	**268.6**	**317.1**	**301.1**	**500**	**4**
Dissolved Oxygen	46	06/14/78-10/18/95	6.8	16	9.6	9.7	10.8	-	-
S. Cond. (µmhos/cm)	46	06/14/78-10/18/95	189	532	362.9	396.7	434.7	-	-
Chromium	5	08/25/83-09/10/91	0.001	0.01	0.01	0.007	-	0.05	0
Cadmium	25	06/14/78-10/18/95	0.001	0.01	0.0064	0.0044	0.001	0.01	0
Mercury	17	06/14/78-09/10/91	0.0002	0.0002	0.0002	0.0002	-	0.002	0
Arsenic	22	06/14/78-10/18/95	0.001	0.02	0.0044	0.005	0.001	0.05	0
Lead	26	06/14/78-10/18/95	0.001	0.01	0.0061	0.0049	0.001	0.05	0
Zinc	27	06/14/78-10/18/95	0.002	0.235	0.0329	0.0209	0.0025	5	0
Iron	**57**	**06/14/78-10/18/95**	**0.01**	**1.36**	**0.431**	**0.344**	**0.2769**	**0.3**	**29**
Sulfate	**76**	**06/14/78-10/18/95**	**0.1**	**368**	**49.7**	**68.8**	**38.4**	**250**	**1**
Nitrate	24	06/14/78-10/18/95	0.01	1.32	0.3285	0.0419	0.19	10	0
Orthophosphate	7	06/14/78-10/13/82	0.01	0.11	0.0155	0.0733	0.0225	-	-
Manganese	**58**	**06/14/78-10/18/95**	**0.004**	**0.12**	**0.0316**	**0.0403**	**0.0536**	**0.05**	**15**
Magnesium	76	06/14/78-10/18/95	5.76	60.3	20.2	24.1	20.1	-	-
Calcium	77	06/14/78-10/18/95	13.5	112	61.5	66.8	68.8	-	-
Bicarbonate as HCO_3^-	76	06/14/78-10/18/95	112	350	231	257.6	300.4	-	-
Total Alkalinity as $CaCO_3$	14	05/11/79-06/27/86	160	240.5	195.7	219.5	-	-	-
Total Hardness as $CaCO_3$	22	09/26/84-10/18/95	158	434	262	315.1	-	-	-

As discussed earlier with Whiskey Canyon, a substantial portion of the flow to this stream may also be due to the ground water base flow. However, the actual quantification between runoff and base flow has not been performed so far. In addition, if there is a disturbance to local flow networks associated with nearby faults, then recharge to streams through base flow will be impacted. No conclusion can be made at this stage for any specific reason for reduction in flow except to state that long-term data indicated a gradual reduction of flow in South Fork.

Spring Flow

The only spring available with long-term data was 173438, and this spring is located around 9,280 feet elevation in the Blackhawk Formation. The summary flow information given in Table 10 shows that flow in this spring is small with a Season 1 mean of only 0.0003 cfs. The flow varied from 0 to 0.001 cfs between 1991 and 1996. Also, due to a limited number of data points, only 11, the time-series plot given in Figure 23 provides an erratic behavior where no conclusion can be made. Table A6 in Appendix A indicates no trend with poor probability. Therefore, it can be concluded that data are too limited from this spring to make any significant conclusion related to flow behavior. Recent communication with Ken Wyatt of DOGM indicated that this spring dried up last year and may have reappeared a few hundred feet away from the original location due to changes in the flow pathways.

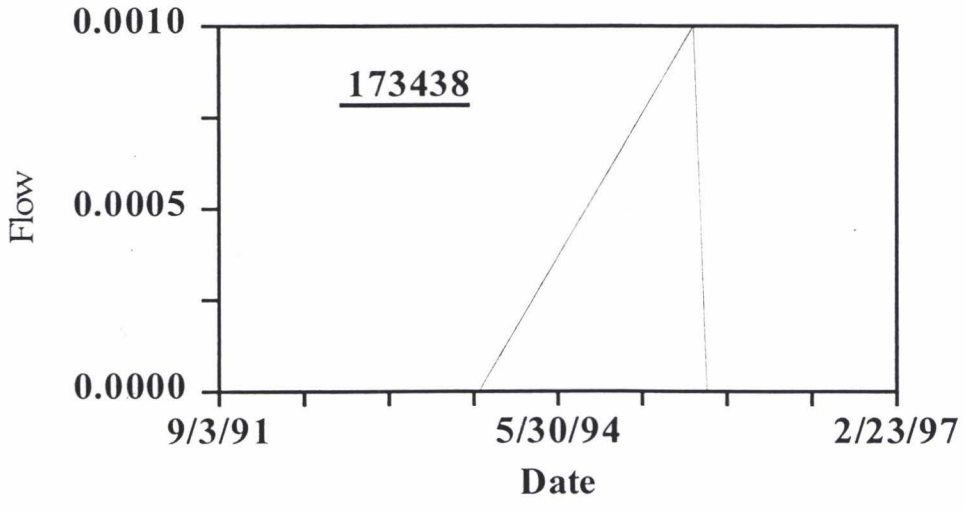


Figure 23: Time-series distribution of flow at Station 173438.

Table 10. Summary water quality data at Spring 173438 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	11	09/03/91-09/12/96	0	0.001	0.0003	0	-	-	-
pH	**38**	**06/29/82-07/24/95**	**6.2**	**7.7**	**6.9**	**6.9**	**-**	**6.5-8.5**	**0**
TSS	**26**	**06/29/82-07/24/95**	**1**	**3262**	**476**	**130.3**	**-**	**-**	**-**
TDS	26	06/29/82-07/24/95	222	325	260	286.9	-	500	0
Dissolved Oxygen	8	08/19/82-09/10/90	2.8	7.2	-	4.3	-	-	-
S. Cond. (µmhos/cm)	38	06/29/82-07/24/95	227	673	472.1	458.5	-	-	-
Lead	9	08/19/82-09/10/90	0.001	0.009	-	0.003	-	0.05	0
Zinc	7	08/19/82-08/17/88	0.005	0.118	-	0.0387	-	5	0
Iron	**26**	**06/29/82-07/24/95**	**0.03**	**277**	**4.4**	**20.2**	**-**	**0.3**	**17**
Sulfate	26	06/29/82-07/24/95	3	42	10	15.9	-	250	0
Nitrate	14	08/19/82-06/19/91	0.02	0.96	0.4567	0.47	-	10	0
Orthophosphate	1	07/24/95	0.01	0.01	0.01	-	-	-	-
Manganese	**26**	**06/29/82-07/24/95**	**0.0024**	**0.44**	**0.0723**	**0.0502**	**-**	**0.05**	**8**
Magnesium	18	06/29/82-07/24/95	2.9	30.7	11.6	17.6	-	-	-
Calcium	18	06/29/82-07/24/95	55.6	104.8	76.4	77.6	-	-	-
Bicarbonate as HCO_3^-	26	06/29/82-07/24/95	226.9	359	291.7	316.8	-	-	-
Total Alkalinity as $CaCO_3$	9	08/19/82-09/10/90	245	285	-	267.3	-	-	-

Water Quality of South Fork

Table 8 provides the summary water quality data at the upstream station 173414 where it is seen that TDS, lead, iron, and manganese are the COC. However, compared to the background values given in Table 3, it can be concluded that these concentrations from 1982 to 1997 are close to the background values. Also, any elevated concentration shown may be due to natural geochemical reactions between formation materials and water entering the stream as base flow or surface runoff. The dissolved oxygen concentration was high indicating good aerobic conditions for fish habitat. The trend analysis given in Table A4 in Appendix A indicates zero trend for lead and a decreasing seasonal trend for iron with good probability. Figures 24a and 24b show the time-series plots of iron and manganese concentrations, respectively. There were no reported data on heavy metals at this station.

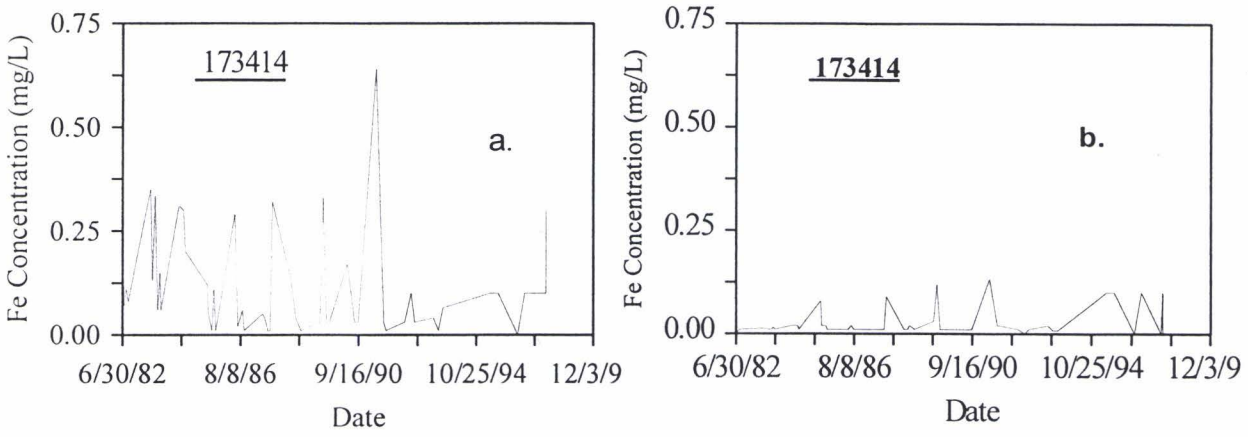


Figure 24: Time-series distributions of iron and manganese at Station 173414.

Table 9 shows the summary water quality data at the downstream station, 173478, where it is seen that TDS, iron, sulfate, and manganese are the COC. Compared to the background values given in Table 3 and the number of occurrences exceeding MCL, it can be concluded that TDS, iron, and manganese may be the only concerns. Sulfate exceeded the MCL only once whereas iron and manganese exceeded the MCLs 29 and 15 times, respectively. High dissolved oxygen concentrations indicate good aerobic conditions and no presence of biodegradable organics. Figure 25a, 25b, and 25c show the time-series plots of TDS, iron

and manganese, respectively. Table A5 in Appendix A indicates that TDS, manganese, and sulfate have increasing seasonal trends with good probability. Since the flow or the quality of water recharging the streams are not known, it is safe to conclude that the water quality of South Fork was not greatly impacted during the period of 1978 through 1995.

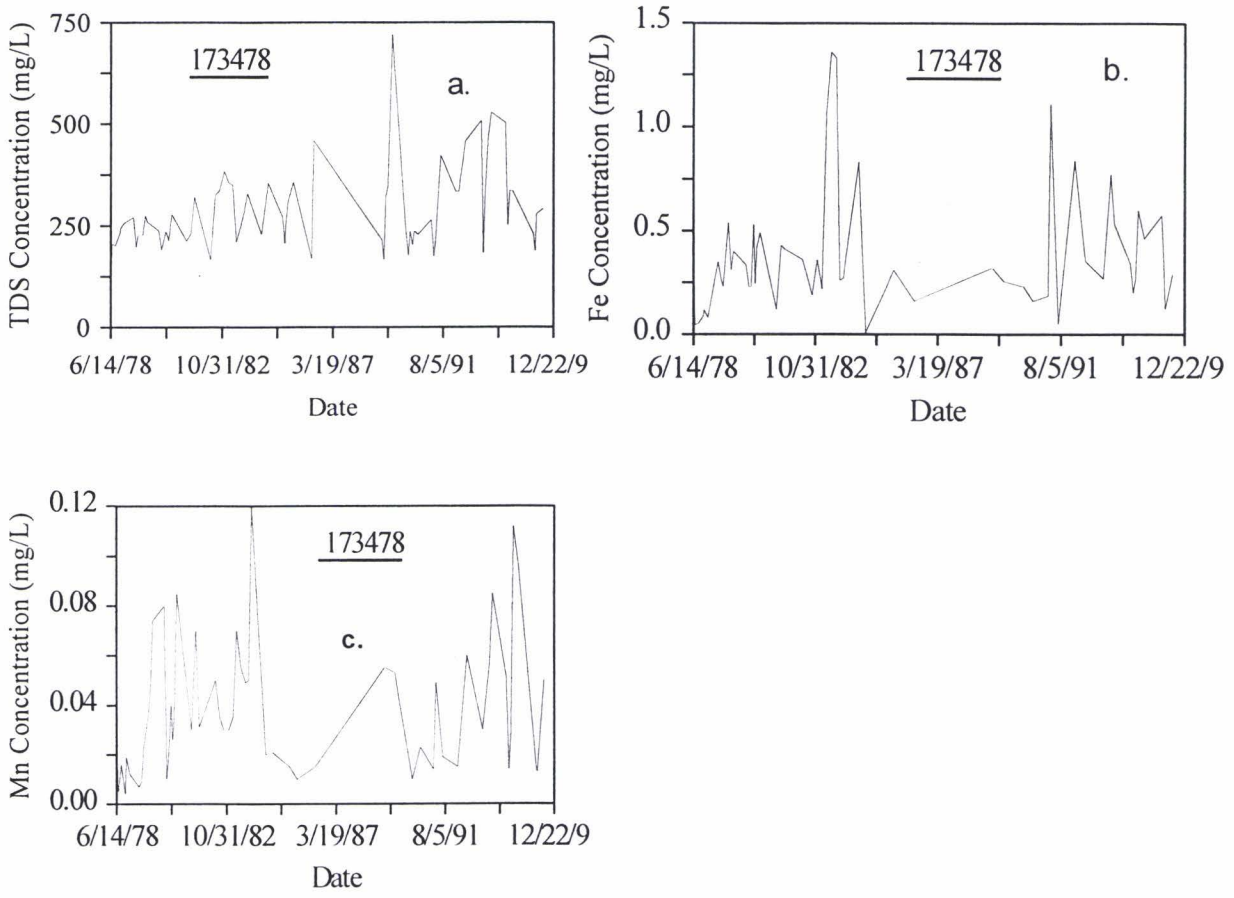


Figure 25: Time-series distributions of TDS, iron, and manganese at Station 173478.

Water Quality of Spring

Table 10 provides the summary data of water quality at Spring 173438. The data indicate the presence of TSS, iron, and manganese as the COC. The iron concentrations were high from 1982 to 1995 exceeding the MCL 17 times and were much higher than the background value given in Table 3. The maximum iron concentration was as high as 277 mg/L in 1986. Figures 26a and 26b show the time-series plots of iron and manganese concentrations in this

spring. Manganese concentration was high during 1985 and prior to this year. Table A6 in Appendix A indicates that TSS, iron, and manganese have decreasing seasonal trends with good probability. Also, Table 10 indicates that TSS is much higher than the background value by one to two orders of magnitude.

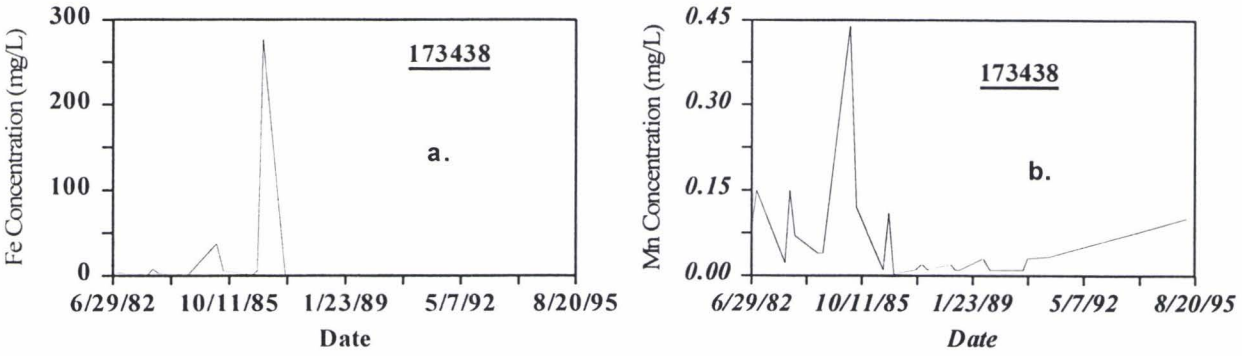


Figure 26: Time-series distributions of iron and manganese at Station 173438.

There is no precise explanation for these high TSS, iron, or manganese concentrations, especially when the spring is located at a high elevation, and far away from coal mining operations. Therefore, it can be speculated that natural geochemical reactions between the recharge water to the spring and the formation materials, such as Mancos Shale, may be partly responsible for these elevated concentrations.

4.2.4 Eccles Creek

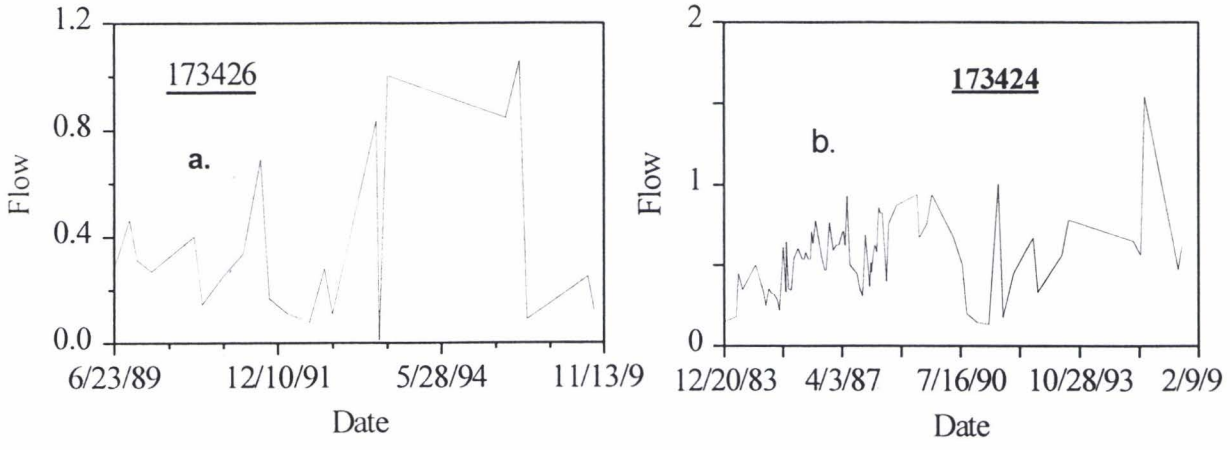
Eccles Creek flows from west to east from the Skyline Mine area to join Mud Creek (Figures 13 and 14). Whiskey Canyon and South Fork are the main tributaries joining Eccles Creek before it joins Mud Creek. Previous studies have indicated that a part of the flow to Eccles Creek is due to base flow occurring in flow networks associated with the O'Connor Fault (White Oak Mine Permit Documentation, 1995). Although not quantified rigorously, the estimated base flow to Eccles Creek is around 200 gpm or 0.446 cfs. Therefore, any disturbance to these flow pathways due to subsidence or any other activities caused by mining may affect the recharge to the creek.

Mine Discharges

There are three mine discharge stations located upstream of Eccles Creek, and these discharges are from the Skyline Mine. Of these discharge points, Stations 173424 and 173426 are direct discharges to sedimentation ponds located in the portal area, and Station 173448 is a UPDES station discharging water to Eccles Creek. Therefore, the first two stations can be viewed as the stations accounting for the flow captured in-mine during coal mining operations and consists of part of the mine interception and part of the water brought from outside for mining purposes.

In addition, there is a UPDES discharge station, 173449, providing flow to Eccles Creek near the Mud Creek intersection. Since the flow in Eccles Creek at this location is a direct contribution to Mud Creek, this UPDES station will be analyzed with data from Mud Creek.

Table 11 shows the flow summary at discharge station 173426, and the trend results are given in Table A7 in Appendix A. The flow data from 1989 to 1996 showed similar values between Seasons 1 and 2, and a 50% reduction during the winter period or Season 3. The flow varied from 0.011 to 1.1 cfs during this period. The trend results are poor with low probability and the same conclusion holds for correlations as well. Figure 27a shows the time-series plot of flow indicating that the flow is high between 1993 and 1995.



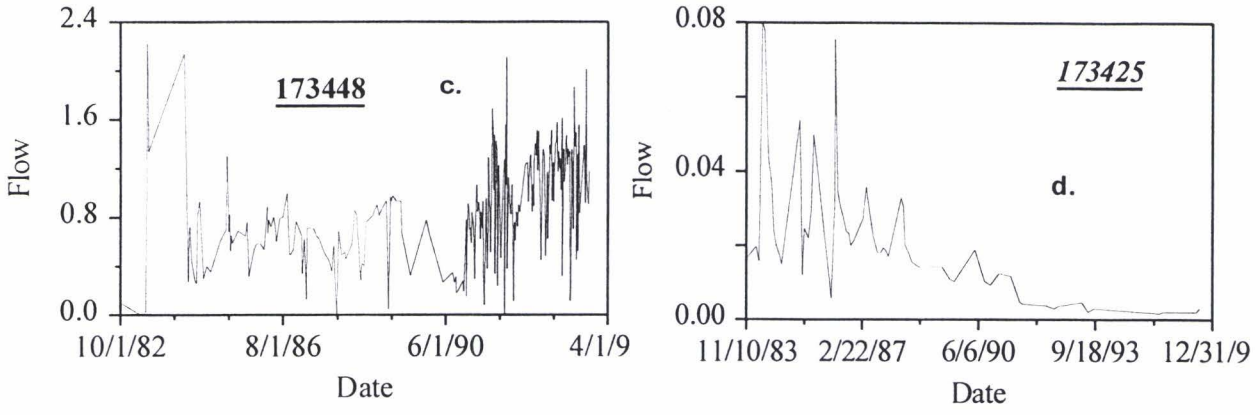


Figure 27: Time-series distributions of flow at Stations 173426, 173424, 173448, and 173425.

Table 12 shows the summary flow data at discharge location 173424 where it is seen that the peak flow was approximately 25% higher than in the upstream discharge station, 173426, over the same period. The flow variability was 0.134 to 1.5 cfs between 1983 and 1996. Table A8 in Appendix A shows that there is an increasing seasonal trend of flow with good probability. However, the correlations were poor due to the presence of other dominant factors affecting the relationship between flow and ET or precipitation. Figure 27b shows the time-series plot of flow at this station where it is clearly seen that there is an increasing seasonal trend of flow.

Table 13 shows the summary flow data at the next downstream discharge location 173448 which is a UPDES discharge location to Eccles Creek. According to Table 13, the flow at this location is much higher than the previous two upstream locations, and remained almost the same during the three seasons; around 0.85 cfs or 382 gpm. The peak flow was 2.2 cfs, and the minimum was 0.002 cfs. This observation may be expected as this station discharges water from the sedimentation ponds which collect the mine discharge first. Table A9 in Appendix A shows that the flow has an increasing seasonal trend with good probability. Figure 27c shows that flow was relatively small from 1983 to 1990, but remained high at all other times.

Table 11. Summary water quality data at Mine Discharge Station 173426 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	23	06/23/89-10/30/96	0.0113	1.1	0.3899	0.4099	0.1977	-	-
pH	**26**	**01/25/89-06/24/97**	**6.5**	**8.2**	**7.5**	**7.6**	**7.5**	**6.5-8.5**	**0**
TSS	**30**	**01/25/89-06/24/97**	**1**	**8070**	**116**	**830**	**537.5**	**-**	**-**
TDS	**61**	**01/25/89-10/30/96**	**405**	**2570**	**1259.9**	**1023.2**	**1019**	**500**	**58**
Dissolved Oxygen	11	09/18/89-06/24/97	3.4	10.2	6.5	6.1	9.5	-	-
S. Cond. (µmhos/cm)	25	01/25/89-06/24/97	406	2740	1268.9	1356.8	1416.2	-	-
Lead	8	01/25/89-09/25/96	0.001	0.1	-	0.0319	0.001	0.05	2
Zinc	1	01/25/89	0.037	0.037	-	-	0.037	5	0
Iron	**26**	**01/25/89-06/24/97**	**0.05**	**19.8**	**1.3**	**3**	**0.85**	**0.3**	**19**
Sulfate	**61**	**01/25/89-09/25/96**	**140**	**1470**	**577.7**	**500.8**	**523**	**250**	**54**
Nitrate	21	01/25/89-06/24/97	0.07	12.3	2.7	2.2	2.9	10	1
Orthophosphate	6	06/20/95-06/24/97	0.01	0.3	0.185	0.03	-	-	-
Manganese	**25**	**01/25/89-06/24/97**	**0.0002**	**0.3**	**0.0576**	**0.1011**	**0.0817**	**0.05**	**15**
Magnesium	52	01/25/89-09/25/96	10	175.6	94.9	83.4	70.6	-	-
Calcium	53	01/25/89-09/25/96	26.1	700	130.3	134.6	158.5	-	-
Bicarbonate as HCO_3^-	31	01/25/89-06/24/97	208	518	294.4	316.9	306.1	-	-
Total Alkalinity as $CaCO_3$	14	01/25/89-10/30/96	177	425	340	271.7	240.7	-	-
Total Hardness as $CaCO_3$	11	06/15/92-06/20/95	81.5	1205.7	684.3	505	426.3	-	-

Table 12. Summary water quality data at Mine Discharge Station 173424 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	81	12/20/83-10/30/96	0.1337	1.5	0.5756	0.6201	0.4906	-	-
pH	**89**	**11/30/83-10/30/96**	**6.8**	**9**	**7.5**	**7.7**	**7.3**	**6.5-8.5**	**1**
TSS	**105**	**11/30/83-10/30/96**	**1**	**4750**	**208.1**	**30.9**	**195.2**	**-**	**-**
TDS	**140**	**11/30/83-10/30/96**	**288**	**2084**	**775.9**	**814.5**	**802.8**	**500**	**105**
Dissolved Oxygen	15	08/24/84-09/25/96	3.9	10.5	6	6.5	9.4	-	-
S. Cond. (µmhos/cm)	87	11/30/83-10/30/96	487	2390	902	1107	929.7	-	-
Lead	13	11/30/83-09/25/96	0.001	0.1	-	0.0199	0.001	0.05	2
Zinc	6	11/30/83-08/15/88	0.003	0.062	-	0.0274	0.003	5	0
Iron	**97**	**11/30/83-10/30/96**	**0.02**	**32.4**	**1.7**	**0.7227**	**1.5**	**0.3**	**50**
Sulfate	**126**	**11/30/83-09/25/96**	**43**	**915**	**355.3**	**374**	**357**	**250**	**85**
Nitrate	29	11/30/83-10/27/93	0.01	340	0.6683	23.6	1	10	1
Orthophosphate	5	06/20/9510/30/96	0.01	0.04	0.04	0.0225	-	-	-
Manganese	**81**	**11/30/83-10/30/96**	**0.0002**	**0.51**	**0.0478**	**0.0567**	**0.0759**	**0.05**	**21**
Magnesium	101	10/30/83-09/25/96	0.1	157	47.8	54.8	45	-	-
Calcium	99	11/30/83-09/25/96	19.7	259.7	96.5	83.4	101.9	-	-
Bicarbonate as HCO_3^-	95	11/30/83-10/30/96	170.8	605	253.9	326.8	263.4	-	-
Total Alkalinity as $CaCO_3$	20	11/30/83-10/30/96	158	490	460	301.5	356	-	-
Total Hardness as $CaCO_3$	13	06/15/92-06/20/95	203	683	468.7	454.9	222.3	-	-

Table 13. Summary water quality data at UPDES Discharge Station 173448 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	248	10/01/82-12/21/93	0.0022	2.2	0.8678	0.8546	0.8236	-	-
pH	**289**	**05/18/83-12/28/93**	**6.6**	**11.8**	**7.7**	**7.7**	**7.7**	**6.5-8.5**	**3**
TSS	313	10/01/82-12/28/93	0.5	185	28.5	22.5	23.7	-	-
TDS	**335**	**10/01/82-07/27/94**	**140**	**1656**	**742**	**854.6**	**783.2**	**500**	**247**
Dissolved Oxygen	23	08/20/86-10/05/93	2.5	12.5	7.4	6.7	7.6	-	-
S. Cond. (µmhos/cm)	272	05/18/83-12/28/93	381	1970	1081.1	1162.3	1038.5	-	-
Chromium	1	10/01/82	0.005	0.005	-	0.005	-	0.05	0
Cadmium	2	10/01/82-12/04/92	0.001	0.004	-	0.001	0.004	0.01	0
Mercury	1	10/01/82	0.0002	0.0002	-	0.0002	-	0.002	0
Arsenic	1	10/01/82	0.002	0.002	-	0.002	-	0.05	0
Lead	1	10/01/82	0.001	0.001	-	0.001	-	0.05	0
Zinc	14	10/01/82-02/11/92	0.012	0.073	0.0225	0.0173	0.0311	5	0
Iron	**284**	**10/01/82-12/28/93**	**0**	**4**	**0.4759**	**0.3449**	**0.3957**	**0.3**	**134**
Sulfate	**115**	**10/01/82-07/27/94**	**0.1**	**900**	**422.6**	**428.7**	**408.3**	**250**	**109**
Nitrate	68	10/01/82-12/14/93	0	5.4	1.1	1.4	1.1	10	0
Manganese	**23**	**10/01/82-02/11/92**	**0.01**	**0.2**	**0.0695**	**0.0571**	**0.0626**	**0.05**	**7**
Magnesium	74	10/01/82-04/27/93	0.1	222.3	53.9	43.5	47.2	-	-
Calcium	82	07/09/87-04/27/93	60.1	383.9	123.9	121.9	131.5	-	-
Bicarbonate as HCO_3^-	82	07/09/87-02/04/93	193	425	231.4	241	264.9	-	-
Total Alkalinity as $CaCO_3$	3	01/20/93-02/04/93	304	349	-	-	330	-	-
Total Hardness as $CaCO_3$	16	12/05/89-02/04/93	449.2	745	581	631.1	574.6	-	-

In general, flows from the two stations located close to the Skyline Mine boundary indicate that mine discharges were relatively high and showed increasing seasonal trends from the 1980's to 1996.

Flow in Seep

Seep 173425 is located close to the loadout sedimentation pond. The actual destination of the water from this location is unknown, but the most likely destination is the nearby sedimentation pond. The summary water flow and quality data are given in Table 14. The data indicate that flow in this seep ranged from 0.0015 to 0.08 cfs between 1983 and 1996. The mean of Season 1 was almost twice that of the other two seasons. Figure 27d shows a clear seasonal trend of reducing flow during this period of 1983 to 1996. This conclusion is further confirmed by Table A10 of Appendix A where the results indicate a reducing seasonal trend with good probability.

Stream Flow

There are six stream stations located along Eccles Creek, and five of these stations are monitored by the Skyline Mine (Figure 14) and the remaining one by USGS (Figure 13). The most upstream station is 173417 and is located above all mine discharge locations. The flow summary of this station is given in Table 15. The data show high flows during Season 1 followed by more than one order of magnitude reduction in other seasons from 1981 through 1997. During this period, the flow varied from 0.006 to 8.4 cfs. Table A11 in Appendix A shows that the flow has a reducing seasonal trend with good probability. Figure 28a shows that the flow was extreme in 1984 and thereafter remained relatively uniform and small.

Stream station 173415 is located downstream of the three mine discharge locations and obtains flow from surface runoff during spring and summer, base flow, minor tributaries, and mine discharges. However, none of these components have been quantified. Table 16 shows the summary water flow data at this station where it is seen that the flow was substantially higher than at the upstream station 173417; for example, the mean of Season 1

Table 14. Summary water quality data at Seep 173425 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	66	11/10/83-10/30/96	0.0015	0.08	0.0299	0.0142	0.0177	-	-
pH	**68**	**11/10/83-10/30/96**	**6.7**	**8.1**	**7.3**	**7.4**	**7.3**	**6.5-8.5**	**0**
TSS	68	11/10/83-10/30/96	0.1	227	16.7	15.1	10.7	-	-
TDS	**68**	**11/10/83-10/30/96**	**360**	**890**	**540.6**	**538.6**	**468.9**	**500**	**31**
Dissolved Oxygen	16	08/24/84-09/25/96	5.2	10.9	5.8	7.9	9.1	-	-
S. Cond. (µmhos/cm)	67	11/10/83-10/30/96	591	1338	879.7	864.4	714.5	-	-
Lead	**12**	**08/24/84-09/25/96**	**0.001**	**0.1**	**-**	**0.0203**	**-**	**0.05**	**2**
Zinc	5	08/24/84-08/16/88	0.005	0.056	-	0.0202	-	5	0
Iron	**67**	**11/10/83-10/30/96**	**0.01**	**1.3**	**0.2312**	**0.219**	**0.1487**	**0.3**	**13**
Sulfate	66	11/10/83-09/25/96	30.4	290	111.9	119.6	86.6	250	1
Nitrate	21	08/24/84-10/28/93	0.01	0.95	0.136	0.2554	0.1267	10	0
Orthophosphate	7	08/22/85-10/30/96	0.01	0.03	0.03	0.016	-	-	-
Manganese	**67**	**11/10/83-10/30/96**	**0.0003**	**0.6**	**0.08**	**0.0791**	**0.0299**	**0.05**	**24**
Magnesium	44	11/10/83-09/25/96	2.4	53.3	31.8	34	27.7	-	-
Calcium	44	11/10/83-09/25/96	65.6	204	118.1	119.6	112	-	-
Bicarbonate as HCO_3^-	68	11/10/83-10/30/96	240.3	437	359.7	361	355.5	-	-
Total Alkalinity as $CaCO_3$	14	08/24/84-10/30/96	234	359	350	300.2	-	-	-
Total Hardness as $CaCO_3$	7	06/15/92-06/20/95	404	660	514.3	462.3	-	-	-

Table 15. Summary water quality data at Stream Station 173417 of upper Left Fork of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	65	07/29/81-06/24/97	0.0055	8.4	0.7093	0.0443	0.0238	-	-
pH	**65**	**06/29/82-06/24/97**	**6.8**	**8.5**	**7.7**	**7.9**	**7.9**	**6.5-8.5**	**0**
TSS	69	07/29/81-06/24/97	1	747	37	28.3	31.7	-	-
TDS	69	07/29/81-06/24/97	130	365	185.3	258.2	282.5	500	0
Dissolved Oxygen	21	07/29/82-06/24/97	5.8	12.1	8.4	8.1	10.2	-	-
S. Cond. (µmhos/cm)	64	06/29/82-06/24/97	166	563	321.9	417.7	401.3	-	-
Chromium	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/11/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	**15**	**11/11/81-09/16/96**	**0.001**	**0.189**	**-**	**0.0291**	**0.001**	**0.05**	**3**
Zinc	7	11/11/81-08/15/88	0.002	0.075	-	0.0205	0.007	5	0
Iron	**69**	**07/29/81-06/24/97**	**0.01**	**13.5**	**0.6719**	**0.5044**	**0.2167**	**0.3**	**16**
Sulfate	67	07/29/81-09/16/96	0.1	114	14.8	19	25.5	250	0
Nitrate	24	11/11/81-10/27/93	0.02	1.4	0.256	0.3	0.77	10	0
Orthophosphate	7	06/19/95-06/24/97	0.02	0.05	0.0367	0.035	-	-	-
Manganese	**69**	**07/29/81-06/24/97**	**0.002**	**0.245**	**0.0338**	**0.0363**	**0.0175**	**0.05**	**12**
Magnesium	47	07/29/81-09/16/96	0.1	26.4	6.9	10.9	15.1	-	-
Calcium	47	07/29/81-09/16/96	35.2	96	55.1	73.2	78.6	-	-
Bicarbonate as HCO_3^-	69	07/29/81-06/24/97	113	429	181.9	265.5	276.5	-	-
Total Alkalinity as $CaCO_3$	20	10/22/81-10/30/96	120	2465	151.8	361.2	219.7	-	-
Total Hardness as $CaCO_3$	7	06/15/92-06/19/95	130	260	183.3	239.8	-	-	-

Table 16. Summary water quality data at Stream Station 173415 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	61	08/19/82-06/24/97	0.0196	16.6	3.5	1.2	1	-	-
pH	**81**	**04/15/82-06/24/97**	7	**8.5**	**7.7**	**7.8**	**7.6**	**6.5-8.5**	**0**
TSS	**88**	**07/29/81-06/24/97**	**0.1**	**1828**	**149.9**	**28.3**	**19.2**	-	-
TDS	**88**	**07/29/81-06/24/97**	**156**	**1246**	**405.5**	**548.2**	**411.9**	**500**	**25**
Dissolved Oxygen	29	07/29/81-06/24/97	3.9	11	8.8	7.5	9.5	-	-
S. Cond. (µmhos/cm)	80	04/15/82-06/24/97	224	1650	617.2	833.7	653.9	-	-
Chromium	1	11/11/81	0.002	0.002	-	-	0.002	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/11/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	**15**	**11/11/81-09/25/96**	**0.001**	**4.1**	-	**0.3078**	**0.003**	**0.05**	**3**
Zinc	7	11/11/81-08/16/88	0.01	0.268	-	0.0595	0.01	5	0
Iron	**88**	**07/29/81-06/24/97**	**0.01**	**31.2**	**2.2**	**0.5458**	**0.5295**	**0.3**	**67**
Sulfate	**87**	**07/29/81-09/25/96**	**3**	**647**	**129.1**	**129.5**	**96.9**	**250**	**18**
Nitrate	24	11/11/81-10/28/93	0.02	5	1.2	1.08	2.8	10	0
Orthophosphate	6	06/20/95-06/24/97	0.01	0.06	0.0333	0.0367	-	-	-
Manganese	**88**	**07/29/81-06/24/97**	**0.0011**	**0.64**	**0.1203**	**0.1392**	**0.2479**	**0.05**	**78**
Magnesium	66	07/29/81-09/25/96	8.4	82.9	26.2	34	21.5	-	-
Calcium	66	07/29/81-09/25/96	19.2	128.8	73.7	85.9	89.1	-	-
Bicarbonate as HCO_3^-	87	07/29/81-06/24/97	122	480	238.3	308.2	313	-	-
Total Alkalinity as $CaCO_3$	23	10/23/81-09/25/96	140.2	310	187.7	252.1	262	-	-
Total Hardness as $CaCO_3$	7	06/15/92-06/20/95	310	560	447	453.3	-	-	-

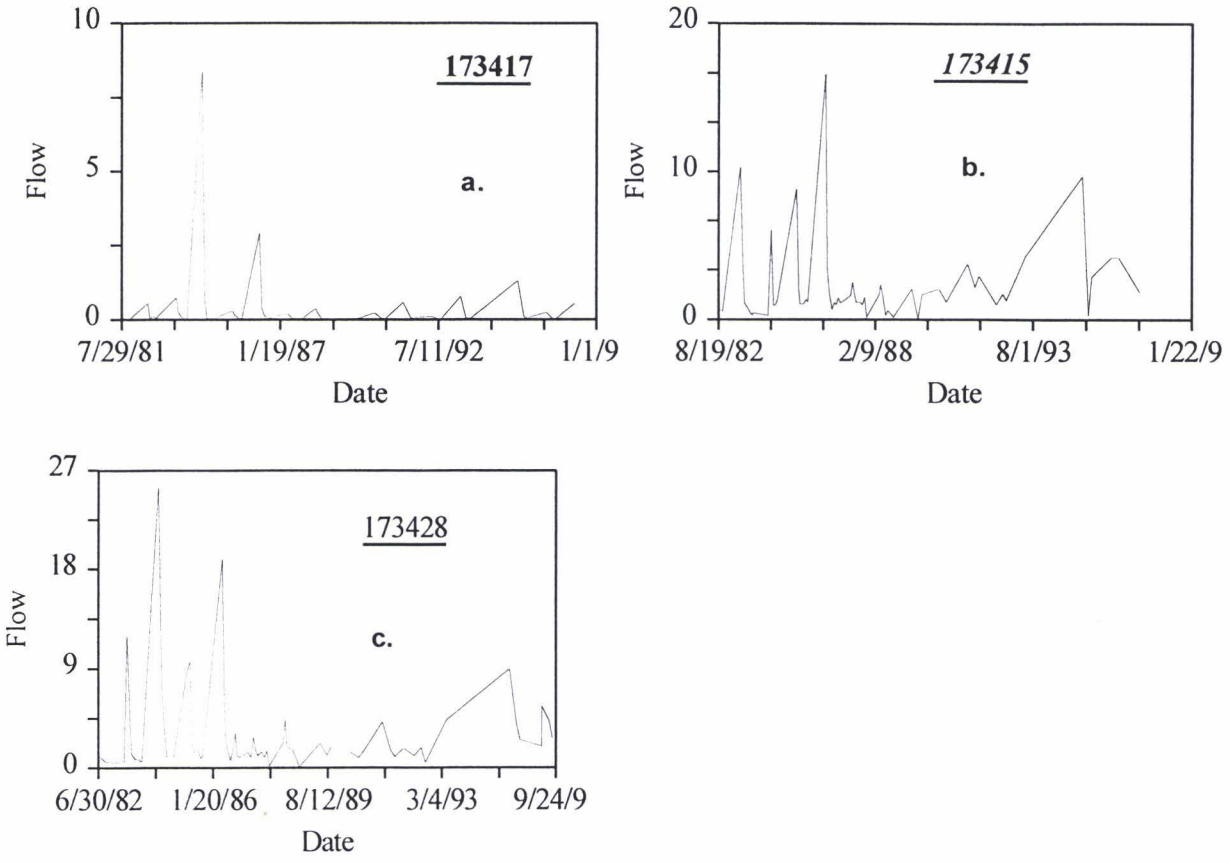


Figure 28: Time-series distributions of flow at Stations 173417, 173415, and 173428.

was five-fold higher, and the mean of Season 2 was more than one order of magnitude higher. Also, the mean of Season 1 was three times higher than Season 2 or 3 indicating substantial flow during the spring and summer. The reported maximum flow at this station was 16.6 cfs. Table A12 in Appendix A shows a substantial increasing seasonal trend with good probability. Figure 28b shows relatively high flow prior to 1988 and in 1994.

The next stream station, 173428, is located after South Fork which contributes flow to Eccles Creek. Table 17 shows the summary flow data at this station where it is clearly seen that seasonal means are higher than at Station 173415. One obvious reason is the flow

Table 17. Summary water quality data at Stream Station 173428 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	73	06/30/82-10/30/96	0.1	25.4	4.7	1.5	0.8467	-	-
pH	**101**	**05/20/82-10/30/96**	**7.3**	**8.7**	**8**	**8**	**7.9**	**6.5-8.5**	**3**
TSS	**106**	**07/29/81-10/30/96**	**1**	**1950**	**209**	**61.4**	**27.6**	**-**	**-**
TDS	**105**	**07/29/81-10/30/96**	**148**	**1214**	**401.2**	**586.4**	**505.9**	**500**	**39**
Dissolved Oxygen	33	07/29/81-09/26/96	5.8	11.9	8.8	8.1	9.8	-	-
S. Cond. (µmhos/cm)	101	05/20/82-10/30/96	248	1590	613	866.9	746.2	-	-
Chromium	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/11/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	15	11/11/81-09/26/96	0.001	0.1	-	0.0164	0.001	0.05	2
Zinc	7	11/11/81-08/16/88	0.007	0.055	-	0.0188	0.015	5	0
Iron	**105**	**07/29/81-10/30/96**	**0.04**	**28**	**2.6**	**0.9098**	**0.4541**	**0.3**	**70**
Sulfate	**103**	**07/29/81-09/26/96**	**3**	**632**	**135.5**	**228.9**	**158.1**	**250**	**29**
Nitrate	30	11/11/81-06/24/96	0.02	5	0.8443	1.1	1.9	10	0
Orthophosphate	9	08/28/84-10/30/96	0.01	0.08	0.0267	0.055	-	-	-
Manganese	**105**	**07/29/81-10/30/96**	**0.0001**	**1.1**	**0.1409**	**0.1385**	**0.168**	**0.05**	**94**
Magnesium	75	07/29/81-09/26/96	0.1	79.7	23.8	38	25.2	-	-
Calcium	75	07/29/81-09/26/96	20.8	146	76.8	87.3	94.1	-	-
Bicarbonate as HCO_3^-	106	07/29/81-10/30/96	15	485	236.8	293.1	284.4	-	-
Total Alkalinity as $CaCO_3$	22	10/23/81-10/30/96	25	318	210	230.6	269.8	-	-
Total Hardness as $CaCO_3$	7	06/15/92-06/20/95	300	557	395.3	505	-	-	-

contribution from South Fork where the flow ranged from 0 to 10.2 cfs from 1978 to 1995, whereas the present station has a range of flow of 0.1 to 25.4 from 1982 to 1996. Since the total discharge from the mine was around 0 to 2.2 cfs over the same period, the net contribution from mine discharges to Eccles Creek remained around 10% or less. Table A13 in Appendix A shows an increasing seasonal trend of 0.123 cfs per year with good probability. Figure 28c shows the time-series distribution of flow at this station where it is seen that the flow was high prior to 1986 and increased again after 1993.

The USGS gaging station, 09310600, is located further downstream from the previous stream station and also downstream of the Whiskey Canyon intersection. The data from this station are limited and available from May 1982 to September 1984. The summary flow data are given in Table 18 where a high mean of 16.1 cfs was present for Season 1. The time-series plot of flow is shown in Figure 29a where it is seen that flow peaked around the summer of 1983, which is in agreement with upstream stream stations. The results suggest that high recharge to the watershed during 1983 may have contributed to high flows in surface runoff, base flow, and in tributaries.

The next stream station, 173418, is located downstream from the previous USGS station and close to Mud Creek. The summary flow data at this station are given in Table 19 where it is seen that flow varied from 1.3 to 71.2 cfs between 1981 and 1997. Also, the seasonal means are almost three-fold higher than at the previous station 173428 indicating additional flow to Eccles Creek from Whiskey Canyon, surface runoff, and base flow. Since there are no reported mine discharge locations between this station and 173428, it can be concluded that the majority of the increase may be due to runoff and base flow since the maximum flow in Whiskey Canyon was less than 3.7 cfs. The trend results of flow given in Table A14 in Appendix A are poor. Figure 29b shows the time-series distribution of flow where it is seen that the flow was relatively high prior to 1987.

The final stream station, 173452, is located just upstream of the Mud Creek intersection, and the summary flow data are given in Table 20. It should be noted here that data from this station are available from 1987 through 1996 only, and the flow varied from 1.9 to 13.7 cfs.

Table 18. Summary water quality data at Stream Station 09310600 of Eccles Creek in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	73	5/12/82-9/25/84	1.8	49	16.1	3.55	-	-	-
pH	**42**	**7/17/79-10/24/84**	**7.4**	**8.6**	**8.3**	**8.2**	**8.2**	**6.5-8.5**	**3**
TDS	**31**	**10/16/80-10/24/84**	**182**	**533**	**263**	**322**	**336**	**500**	**1**
Dissolved Oxygen	38	7/17/79-10/24/84	7.6	10.5	8.7	8.6	9.8	-	-
S. Cond. (µmhos/cm)	60	7/17/79-10/24/84	285	880	444	557	559	-	-
Cadmium	11	5/19/81-10/24/84	0	0.001	0.0008	0.0008	0	0.01	-
Lead	11	5/19/81-10/24/84	0	0.03	0.0136	0.001	0	0.05	-
Zinc	11	5/19/81-10/24/84	0.01	0.33	0.13	0.04	0.07	5	-
Iron	**31**	**10/16/80-10/24/84**	**0.4**	**28**	**7**	**2.7**	**1.6**	**0.3**	**31**
Orthophosphate	13	12/12/79-6/15/84	0	0.31	0.0988	0	0.015	-	-
Manganese	**31**	**10/16/80-10/24/84**	**0.06**	**0.86**	**0.26**	**0.1633**	**0.145**	**0.05**	**31**
Bicarbonate as HCO_3^-	25	7/17/79-9/2/81	200	360	270	307	313	-	-
Total Alkalinity as $CaCO_3$	31	7/17/79-9/2/81	130	300	210	256	258	-	-
Total Hardness as $CaCO_3$	44	7/17/79-10/24/84	150	440	224	306	298	-	-

Table 19. Summary water quality data at Stream Station 173418 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	67	11/11/81-06/24/97	1.3	71.2	11	3	2.7	-	-
pH	**97**	**11/11/81-06/24/97**	**7.2**	**8.8**	**8**	**8**	**7.9**	**6.5-8.5**	**4**
TSS	**103**	**07/29/81-06/24/97**	**1.4**	**3190**	**226.2**	**31.8**	**36**	**-**	**-**
TDS	**103**	**07/29/81-06/24/97**	**198**	**1282**	**403.6**	**493.2**	**440.6**	**500**	**26**
Dissolved Oxygen	31	07/29/81-06/24/97	5.4	11.7	8.7	8.5	9.8	-	-
S. Cond. (µmhos/cm)	95	11/11/81-06/24/97	286	2240	689.3	762	687.8	-	-
Chromium	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/11/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	15	11/11/81-09/25/96	0.001	0.1	-	0.0164	0.001	0.05	2
Zinc	7	11/11/81-08/16/88	0.005	0.025	-	0.0127	0.02	5	0
Iron	**102**	**07/29/81-06/24/97**	**0.14**	**24.5**	**2.6**	**0.6927**	**0.7854**	**0.3**	**95**
Sulfate	**100**	**07/29/81-09/25/96**	**3**	**405**	**88**	**156.4**	**101.2**	**250**	**10**
Nitrate	26	11/11/81-10/28/93	0.02	2.5	0.602	0.732	0.7983	10	0
Orthophosphate	7	06/20/95-06/24/97	0.01	0.07	0.0433	0.025	-	-	-
Manganese	**102**	**07/29/81-06/24/97**	**0.0001**	**0.74**	**0.1433**	**0.0946**	**0.1223**	**0.05**	**89**
Magnesium	75	07/29/81-09/25/96	0.1	65	21	36.4	26.9	-	-
Calcium	73	07/29/81-09/25/96	40.8	158	75.9	79.9	87.1	-	-
Bicarbonate as HCO_3^-	103	07/29/81-06/24/97	144	386	247.3	297.2	300	-	-
Total Alkalinity as $CaCO_3$	25	10/23/81-10/30/96	178.3	316.4	227	251.1	264	-	-
Total Hardness as $CaCO_3$	7	06/16/92-06/20/95	290	468	360	416.5	-	-	-

Table 20. Summary water quality data at Stream Station 173452 of Eccles Creek in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	19	11/19/87-10/30/96	1.9	13.7	7	3	2.8	-	-
pH	**103**	**03/31/82-10/30/96**	7	**8.8**	**8**	**8**	**8**	**6.5-8.5**	**3**
TSS	**110**	**07/29/81-10/30/96**	**1.3**	**4166**	**263.9**	**37.7**	**34.9**	-	-
TDS	**110**	**07/29/81-10/30/96**	**176**	**1320**	**436.5**	**493.4**	**443.6**	**500**	**27**
Dissolved Oxygen	33	07/29/81-09/25/96	3.4	12.4	8.9	8.7	10.4	-	-
S. Cond. (µmhos/cm)	103	03/31/82-10/30/96	296	2280	758.7	773.8	705.6	-	-
Chromium	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	2	11/11/81-05/2082	0.0002	0.0002	0.0002	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	15	11/11/81-09/25/96	0.001	0.1	-	0.0162	0.001	0.05	2
Zinc	7	11/11/81-08/16/88	0.005	0.03	-	0.0122	0.01	5	0
Iron	**109**	**07/29/81-10/30/96**	**0.03**	**36.2**	**3.1**	**0.567**	**0.6797**	**0.3**	**85**
Sulfate	**107**	**07/29/81-09/25/96**	**4**	**426**	**101.8**	**151.9**	**107.6**	**250**	**13**
Nitrate	27	11/11/81-10/28/93	0.02	2.6	0.626	0.56	1.1	10	0
Orthophosphate	8	08/28/84-10/30/96	0.01	0.08	0.035	0.0333	-	-	-
Manganese	**109**	**07/29/81-10/30/96**	**0.0001**	**0.74**	**0.1253**	**0.078**	**0.1077**	**0.05**	**89**
Magnesium	80	07/29/81-09/25/96	0.09	66.4	22.8	35.1	27.4	-	-
Calcium	80	07/29/81-09/25/96	38.4	184	72.9	78.2	84	-	-
Bicarbonate as HCO_3^-	109	07/29/81-10/31/96	168	389.3	246.4	292.9	288.2	-	-
Total Alkalinity as $CaCO_3$	25	10/23/81-10/30/96	177.5	319.1	213.9	244.6	255.8	-	-
Total Hardness as $CaCO_3$	7		280	430	349.7	412.5	-	-	-

This time period is shorter than that of previous stream stations where the data were available from 1981 or 1982. The time-series distribution of flow data is shown in Figure 29c where it is seen that there is an increasing trend after 1990. This conclusion is in agreement with the results given in Table A15 of Appendix A. Also, Table 20 and Figure 29c indicate that flows and seasonal mean flows are smaller than in upstream locations. This observation is correct as the flows after 1987 in upstream stations were small and comparable to Station 173452. The seasonal means computed from the upstream stations included high flows prior to 1987 and, therefore, the mean flows were high. Also, there are no reported water intake or discharge locations between this station and 173418. Therefore, it will be assumed that the flow data discussed here represent the flow passing downstream from Station 173418 without additional point sources or sinks.

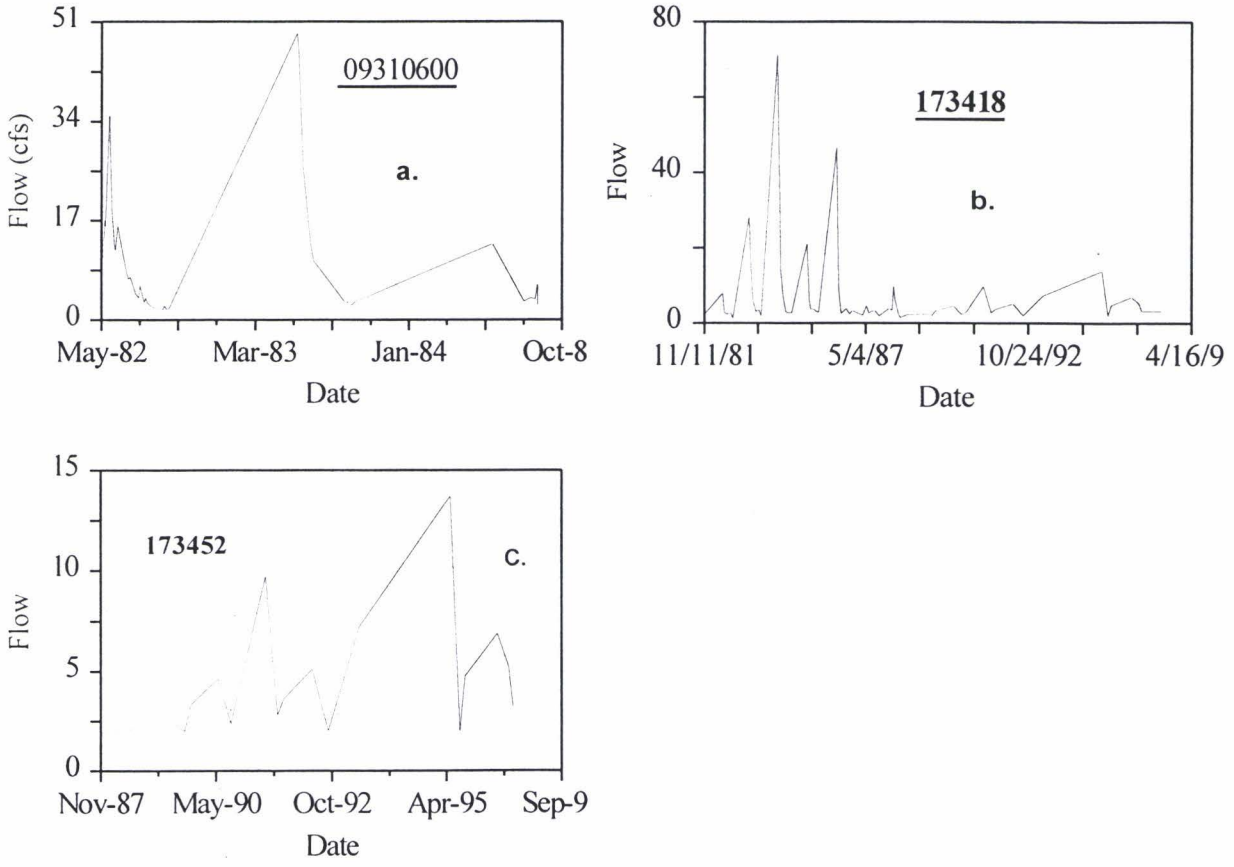


Figure 29: Time-series distributions of flow at Stations 09310600, 173418, and 173452.

The stream flow data between 1981 and 1997 from six stations showed that Eccles Creek continued to have high flows in this reach before discharging to Mud Creek. The flow generally showed an increasing seasonal trend, and the contribution to flow from mine discharges was less than 10%. Also, contributions to flow from other tributaries remained relatively small. Therefore, it can be concluded that much of the flow to Eccles Creek may be due to surface runoff, snowmelt, and base flow through nearby O'Connor Fault.

Spring Flow

There are two springs selected from the Skyline Mine for analysis; these are 173431 located at 8,800 feet of elevation in the Blackhawk Formation, and 173435 located at 8,080 feet of elevation in the Blackhawk Formation. Since these springs are located at high elevations and away from coal mining activities, it is anticipated that flows are not affected directly by mining. However, any subsidence or similar indirect effects due to mining may cause destruction to localized areas of flow, eventually reducing flow.

Table 21 shows the summary flow data at Spring 173431 from 1981 to 1996 where it is seen that the mean of Season 1 was about three-fold higher than that of Seasons 2 or 3. The range of flow during this period was 0 to 0.011 cfs. The trend results, given in Table A16 in Appendix A, are poor. The correlations are also poor with precipitation or ET due to large travel times of subsurface water. The time-series plot of flow given in Figure 30a shows a sharp increase in flow in the summer of 1986 and a gradual increase beyond 1991.

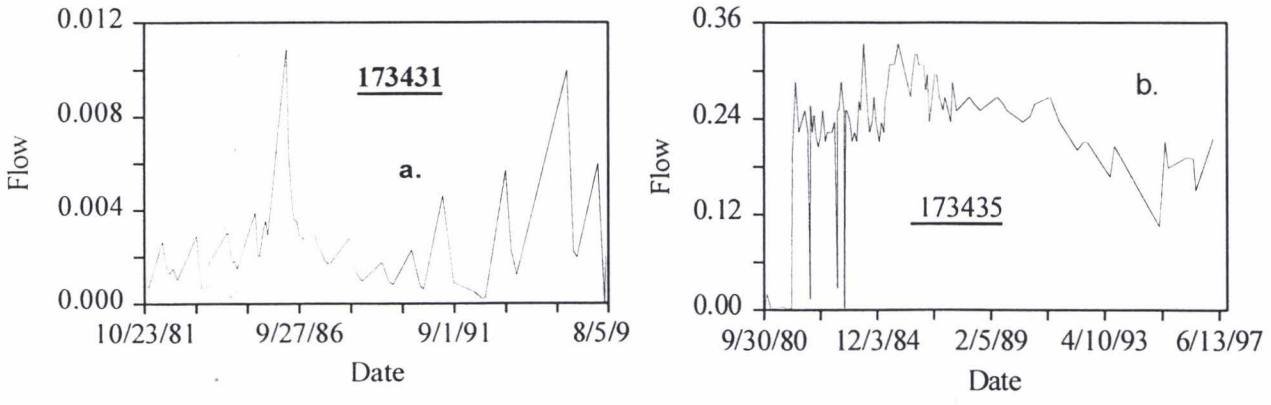


Figure 30: Time-series distributions of flow at Stations 173431, and 173435.

Table 21. Summary water quality data at Spring 173431 in the Price River Watershed obtained from Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	63	10/23/81-09/24/96	0	0.0109	0.0036	0.0016	0.0017	-	-
pH	**62**	**05/20/82-09/24/96**	**6.5**	**8.3**	**7.3**	**7.3**	**7.2**	**6.5-8.5**	**0**
TSS	42	11/12/81-09/24/96	0.1	240	5.8	23.3	36.3	-	-
TDS	**41**	**11/12/81-09/24/96**	**288**	**646**	**326.5**	**349.9**	**455**	**500**	**1**
Dissolved Oxygen	14	08/25/83-09/24/96	5.5	9	6.4	7.3	-	-	-
S. Cond. (µmhos/cm)	62	05/20/82-09/24/96	184	704	559.2	582.4	582	-	-
Chromium	1	11/12/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/12/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/12/81	0.0002	0.0002	-	-	0.002	0.002	0
Arsenic	1	11/12/81	0.001	0.001	-	-	0.001	0.05	0
Lead	**14**	**11/12/81-09/24/96**	**0.001**	**0.1**	**-**	**0.0168**	**0.001**	**0.05**	**2**
Zinc	7	11/12/81-08/15/88	0.002	0.035	-	0.0088	0.035	5	0
Iron	**42**	**11/12/81-09/24/96**	**0.01**	**0.91**	**0.1221**	**0.1148**	**0.3967**	**0.3**	**5**
Sulfate	41	11/12/81-09/24/96	7	280	43.9	50.6	151.7	250	1
Nitrate	23	11/12/81-10/27/93	0.02	5.3	0.72	1.1	1.7	10	0
Orthophosphate	5	06/20/95-09/24/96	0.01	0.03	0.02	0.01	-	-	-
Manganese	**42**	**11/12/81-09/24/96**	**0.001**	**0.1**	**0.0269**	**0.025**	**0.0087**	**0.05**	**6**
Magnesium	30	11/12/81-09/24/96	2.8	54	18.2	23.3	33.8	-	-
Calcium	30	11/12/81-09/24/96	72.1	138	91.3	85.6	106.8	-	-
Bicarbonate as HCO_3^-	41	11/12/81-09/24/96	229.4	356.5	316.7	319.5	302.3	-	-
Total Alkalinity as $CaCO_3$	15	11/12/81-09/24/96	212.9	288	250	268.2	237.7	-	-
Total Hardness as $CaCO_3$	7	06/15/92-06/25/96	271	325	303.3	295	-	-	-

The flow data of the remaining spring, 173435, are given in Table 22 where relatively high flows were present during the entire monitored period; for example, this spring had a flow range of 0.001 to 0.334 cfs whereas the previous spring 173431 had a range of 0 to 0.011 cfs. In addition, the means of all three seasons were almost same, around 0.2 cfs, indicating consistent flow from 1980 to 1997. The time-series flow distribution of this spring is shown in Figure 30b where it is seen that the flow was consistently around 0.2 cfs and started to decline slightly after 1989.

In general, the data suggest that one of the springs, 173435, produced substantially high flows consistently and remained active over the entire monitoring period. The other spring, 173431, provided more uniform flow over all seasons, but at a much lower rate than the other spring. Therefore, the flow data from these two springs indicate no threat of water loss to water users from 1980 to 1997.

Water Quality of Mine Discharges

As discussed earlier, there are three mine discharge locations along Eccles Creek. Two of these stations are direct discharges to sedimentation ponds, and the remaining station is discharging to Eccles Creek through a UPDES permit.

Table 11 shows the water quality summary at mine discharge station 173426 located further upstream of Eccles Creek. The data show high dissolved oxygen concentrations indicating good aerobic conditions and no serious effects due to acid mine drainage. However, TDS, iron, sulfate, and manganese were higher than respective MCLs, and also much higher than the background values given in Table 3. In addition, TSS showed high concentrations compared to the background value. Figures 31a through 31d show the concentrations of TDS, iron, sulfate, and manganese from 1989 to 1997. Table A7 in Appendix A indicates that TDS and manganese have increasing seasonal trends with modest probability whereas the probability of other parameters was poor. According to Table 11, TDS, iron, sulfate, and manganese exceeded the MCLs 58, 19, 54, and 15 times, respectively. The plots indicate that high concentrations of these parameters were visible in mid 1993 to 1994. Since this

Table 22. Summary water quality data at Spring 173435 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	98	19/30/80-06/23/97	0.001	0.334	0.235	0.27	0.21	0.223	-
pH	**98**	**09/11/79-06/23/97**	**6.3**	**7.8**	**7.1**	**7.2**	**7**	**6.5-8.5**	**0**
TSS	51	09/30/80-06/23/97	0.05	28	2.6	5.6	3.8	-	-
TDS	**55**	**09/11/79-06/23/97**	**136**	**535**	**334.3**	**353.8**	**385.4**	**500**	**1**
Dissolved Oxygen	14	08/18/82-09/25/96	4.2	8.7	7.5	5.8	8.7	-	-
S. Cond. (µmhos/cm)	87	04/15/82-06/23/97	311	1496	602	584.4	586.3	-	-
Chromium	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/11/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/11/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/11/81	0.001	0.001	-	-	0.001	0.05	0
Lead	**14**	**11/11/81-09/25/96**	**0.001**	**0.1**	**-**	**0.0168**	**0.001**	**0.05**	**2**
Zinc	8	11/11/81-08/16/88	0.001	0.033	-	0.0097	0.02	5	0
Iron	**54**	**09/30/80-06/23/97**	**0.02**	**1.3**	**0.6347**	**0.6827**	**0.6164**	**0.3**	**41**
Sulfate	55	09/11/79-06/23/97	16	200	49.5	55.6	74.2	250	0
Nitrate	24	11/11/81-06/23/97	0.01	3.4	0.056	0.4113	0.13	10	0
Orthophosphate	6	06/20/95-10/30/96	0.01	0.02	0.015	0.015	-	-	-
Manganese	**54**	**09/30/80-06/23/97**	**0.002**	**0.1**	**0.0449**	**0.0515**	**0.0363**	**0.05**	**19**
Magnesium	43	09/11/79-06/23/97	4.8	47.3	26.4	29.9	30	-	-
Calcium	43	09/11/79-06/23/97	32.8	128	81	78.8	84	-	-
Bicarbonate as HCO_3^-	56	09/11/79-06/23/97	118	405	310.2	316.1	318.2	-	-
Total Alkalinity as $CaCO_3$	25	12/30/80-09/25/96	220	309.9	262	266	266.9	-	-
Total Hardness as $CaCO_3$	6	06/15/92-06/23/97	310	355	332.7	342.3	-	-	-

location eventually provides water to Eccles Creek, the data indicate potential serious water quality concerns to Eccles Creek.

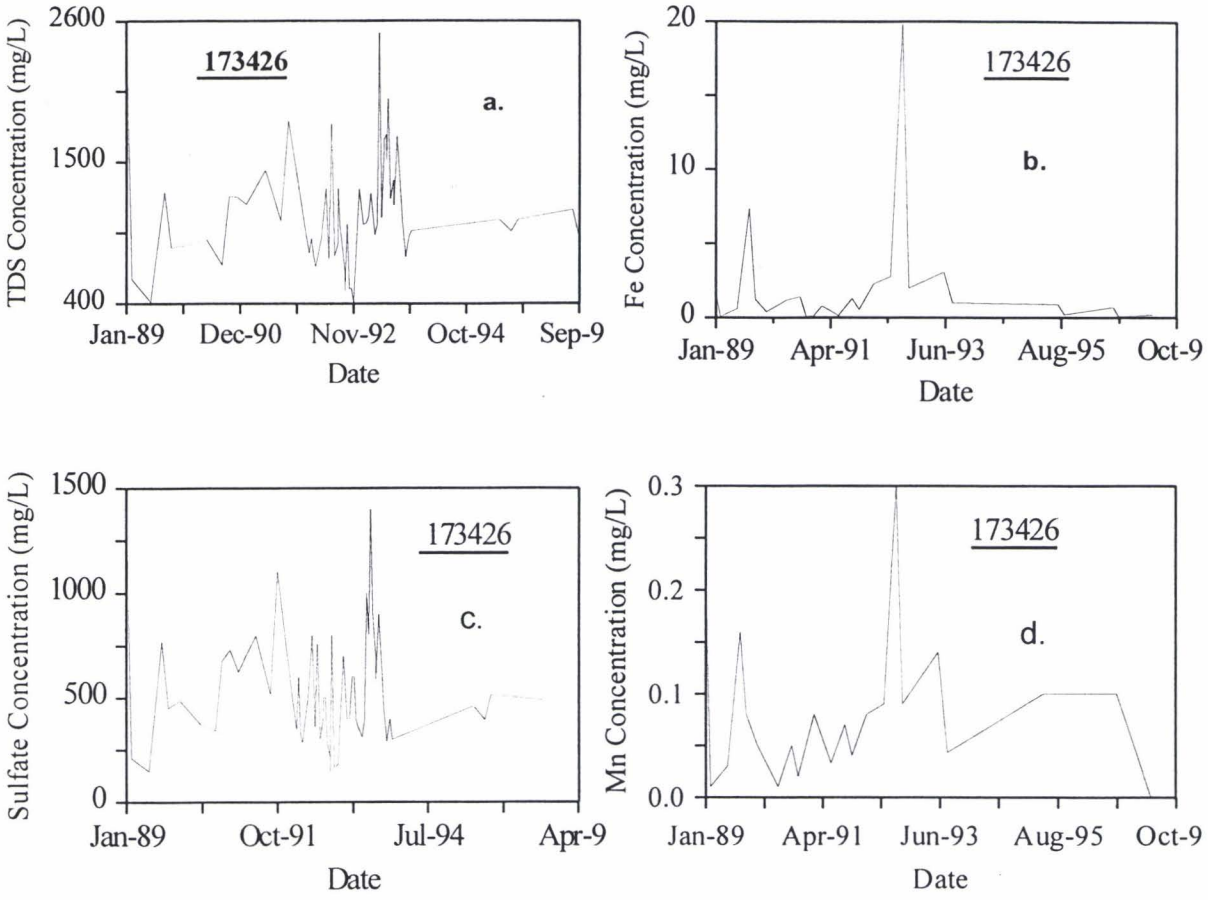


Figure 31: Time-series distributions of TDS, iron, sulfate, and manganese at Station 173426.

Water quality data at the next down stream location, 173424, are shown in Table 12. The data again show that TSS, TDS, iron, sulfate, and manganese are the COC, and the concentrations are much higher than the background values given in Table 3. TDS, sulfate, iron, and manganese exceeded the MCLs 105, 85, 50, and 21 times, respectively, and the maximum observed values of 2084, 915, 32.4, and 0.51 are much higher than the background values. Also, the peak TSS concentration was 4750 mg/L which is much higher than the background value. The data indicate no serious acidic conditions, and the dissolved

oxygen concentration was high indicating good aerobic conditions. Table A8 in Appendix A indicate that TSS had a reducing seasonal trend whereas the other parameters, except manganese, showed increasing seasonal trends. Figures 32a through 32c show the concentrations of TDS, iron, and sulfate between 1983 and 1997. The TDS distribution shows an increasing trend consistently, and sulfate concentrations increased until 1993 and thereafter decreased. Iron concentrations were high during 1984 to early 1985 and reduced thereafter. These results clearly show that both this station and the upstream station have serious water quality concerns that may eventually affect Eccles Creek.

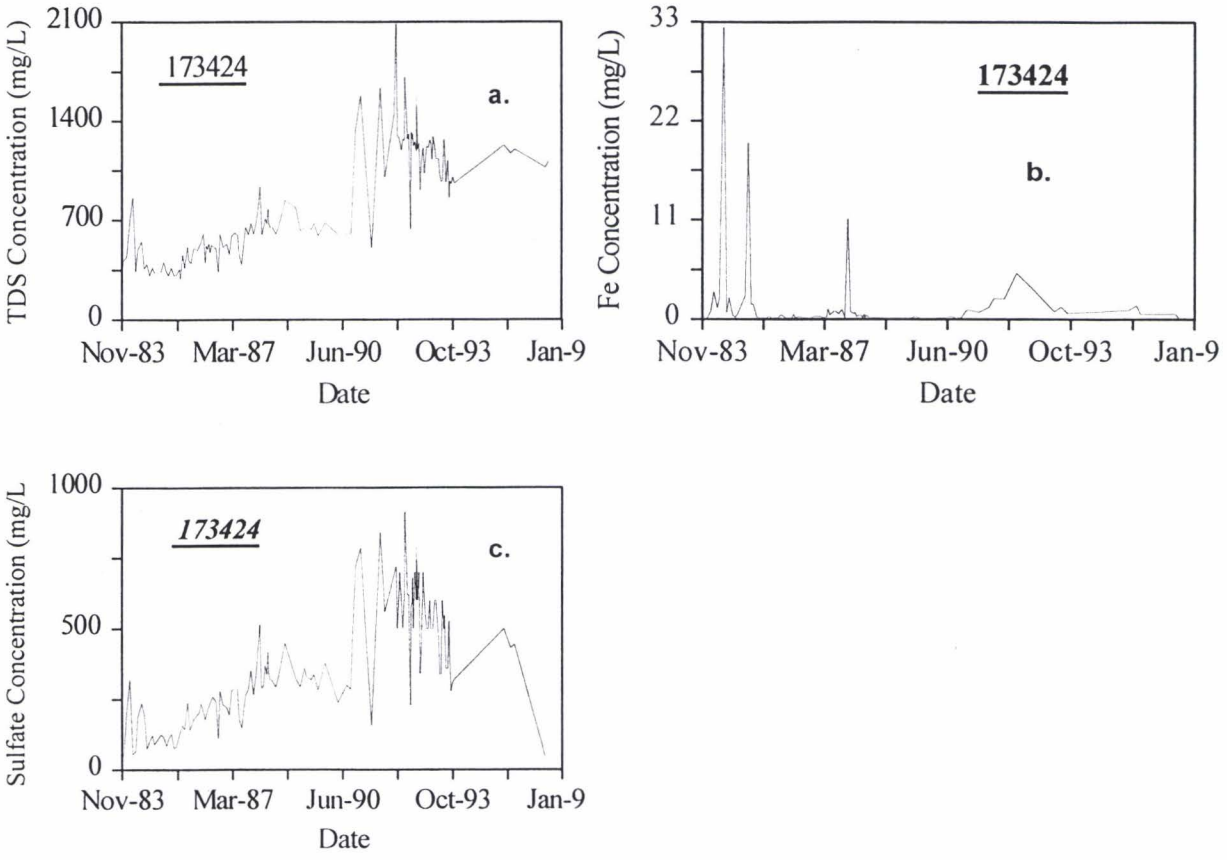


Figure 32: Time-series distributions of TDS, iron, and sulfate at Station 173424.

Table 13 shows the water quality summary at the UPDES station 173448. The data show serious water quality concerns similar to the previous two stations where TDS, iron, sulfate, and manganese are the COC. However, manganese concentration was slightly higher than

the background value given in Table 3. On the other hand, TDS, iron, and sulfate concentrations were much higher than the background concentrations and violated MCLs by 100 to 200 times. The peak TDS, iron, and sulfate concentrations were 1656, 4, and 900 mg/L, respectively. It should be noted that the maximum pH at this station was 11.9 which is much higher than the maximum allowable pH of 8.5. Therefore, it seems that some of the chemicals in the water may be causing excessive pH at this location, which was not observed at any other previous monitoring stations.

Table A9 given in Appendix A indicates increasing seasonal trends of TDS, iron, sulfate, and manganese with good probability, especially TDS which increased at 82.6 mg/L per year. Figures 33a through 33c show time-series distributions of TDS, iron, and sulfate, respectively. It is seen that TDS and sulfate have increasing trends whereas iron showed relatively uniform concentrations with a few spikes. Compared to the data from mine discharges to sedimentation ponds, it can be concluded that this location has much lower concentrations of TSS and other parameters of concern. Although the final destination of water from the sedimentation ponds is unknown, it is quite possible that this water may be discharged through the nearby UPDES station. If this destination is correct, then the possible reason for this reduced concentration may be that sedimentation ponds acted as water treatment units by settling solids carrying large amounts of attached mass. For example, TSS reduced from a range of 4,000 to 8,000 mg/L to 185 mg/L and iron reduced from a range of 20 to 32 mg/L to 4 mg/L.

The data from these three stations did not contain information related to heavy metals. However, the data clearly show that there are serious water quality concerns related to TDS, iron, manganese, and sulfate, and to some extent TSS. Most parameters also indicated increasing seasonal trends with good probability. Two of the locations are discharging to sedimentation ponds, and the final destination of water is Eccles Creek. Therefore, these data suggest the presence of serious water quality concerns in mine discharge water that can eventually affect the quality of water in Eccles Creek.

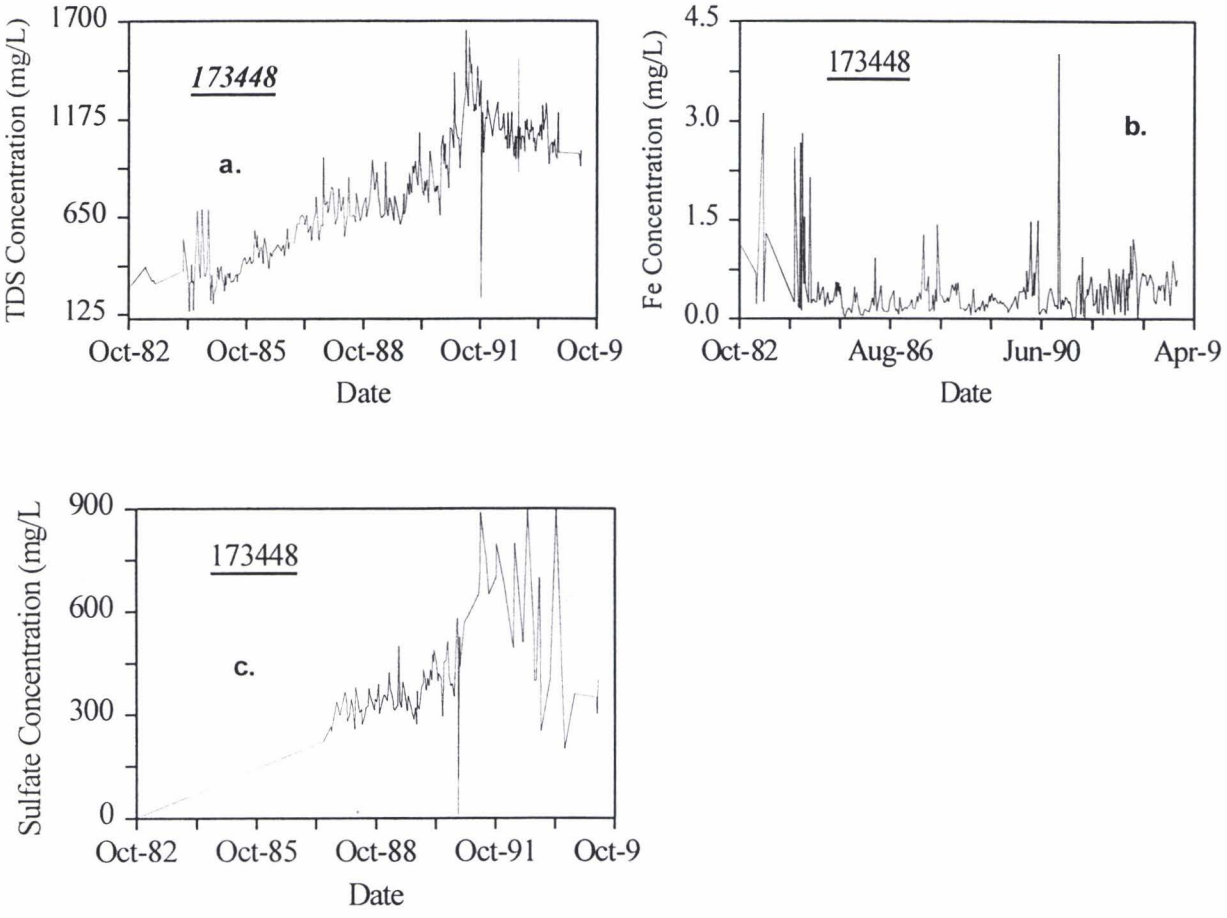


Figure 33: Time-series distributions of TDS, iron, and sulfate at Station 173448.

Water Quality of Seep

The water quality data at this seep, 173425, are given in Table 14. The data show that TDS, lead, iron, and manganese are the COC during 1983 to 1996. However, lead concentration is comparable to the background value given in Table 3 whereas the others show slightly elevated concentrations. Table A10 in Appendix A shows that lead and TDS have increasing seasonal trends with good probability. Figures 34a to 34c show the concentrations of TDS, iron, and manganese. Figure 34a shows a consistent increasing trend of TDS whereas iron and manganese show similar behaviors with little or no increasing trends during the same period. The dissolved oxygen concentration was high in the discharge water, and no serious acid mine drainage problems were detected.

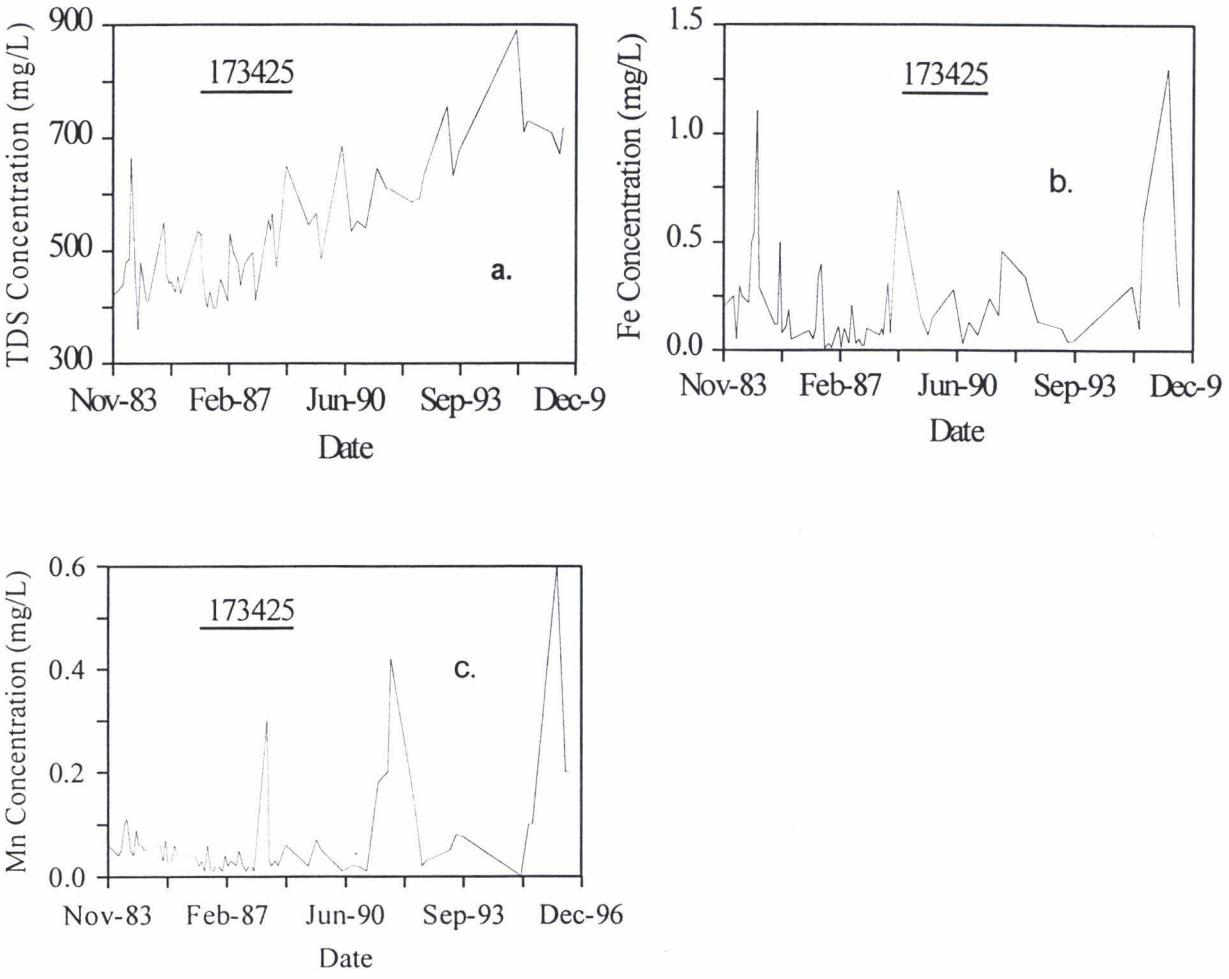


Figure 34: Time-series distributions of TDS, iron, and manganese at Station 173425.

Water Quality of Eccles Creek

The summary water quality data at the most upstream station, 173417, unaffected by mine discharges, are given in Table 15. The data from 1981 to 1997 show lead, iron, and manganese as the COC. The concentrations of lead and manganese are slightly higher than background values given in Table 3 whereas the iron concentration is much higher than both the MCL and the background value. Table A11 in Appendix A indicates that lead and manganese have no trends while iron showed a decreasing seasonal trend with good probability. Figures 35a and 35b show the time-series distributions of iron and manganese. The dissolved oxygen concentration was relatively high indicating good aerobic conditions

and the data show no acid mine drainage concerns. Although there is no obvious interaction of water at this station with coal mining operations or any other land uses, it is difficult to make a definite conclusion related to high iron, lead, or manganese concentrations. It is possible that natural geochemical reactions between water and the formation materials may be contributing to some of these high concentrations.

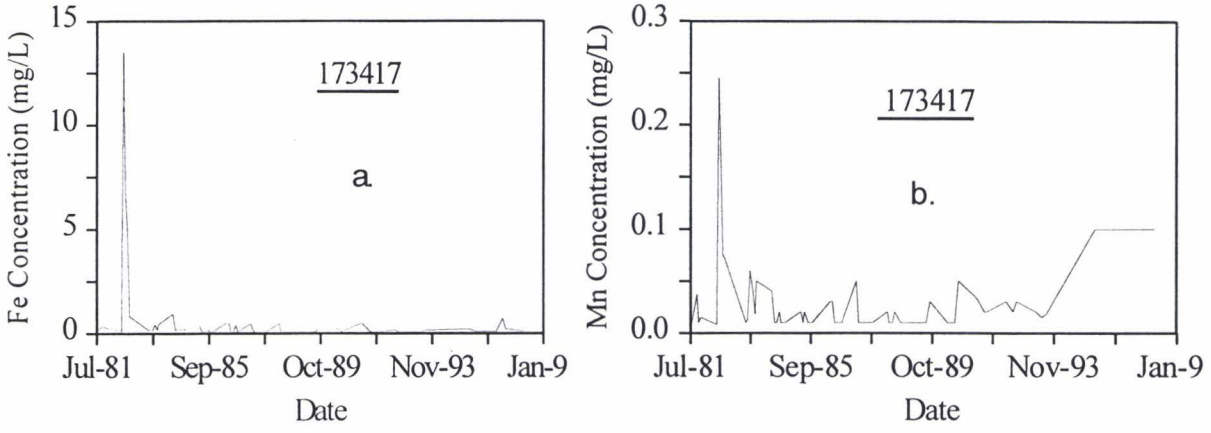


Figure 35: Time-series distributions of TDS and manganese at Station 173417.

The next stream station, 173415, is located downstream of the three mine discharge locations. The summary water data at this station from 1981 to 1997 are given in Table 16. The data show that TSS, TDS, lead, iron, sulfate, and manganese are the COC while the concentrations are much higher than the background values given in Table 3. These parameters also exceeded the MCL by 18 to 78 times except lead by 3 times. The TSS shows high concentrations of up to 1,828 mg/L, TDS up to 1,246 mg/L, lead up to 4.1 mg/L, iron up to 31.2 mg/L, and sulfate up to 647 mg/L. The trend results given in Table A12 of Appendix A indicate that TDS and sulfate have increasing seasonal trends whereas the others have decreasing or zero seasonal trends. Figures 36a and 36c clearly indicate increasing seasonal trends of TDS and sulfate. Figure 36b shows that iron concentrations are relatively uniform except in 1983 and 1984 with a few high concentration spikes. Figure 36d shows relatively high concentrations of manganese with a few spikes prior to 1989.

Compared to the concentrations of the upstream location given in Table 15 before the mine discharges have entered Eccles Creek, it can be concluded that the water quality of this station is very poor. The data from these monitoring stations indicate that poor water quality of mine discharges from upstream locations may have impacted Eccles Creek.

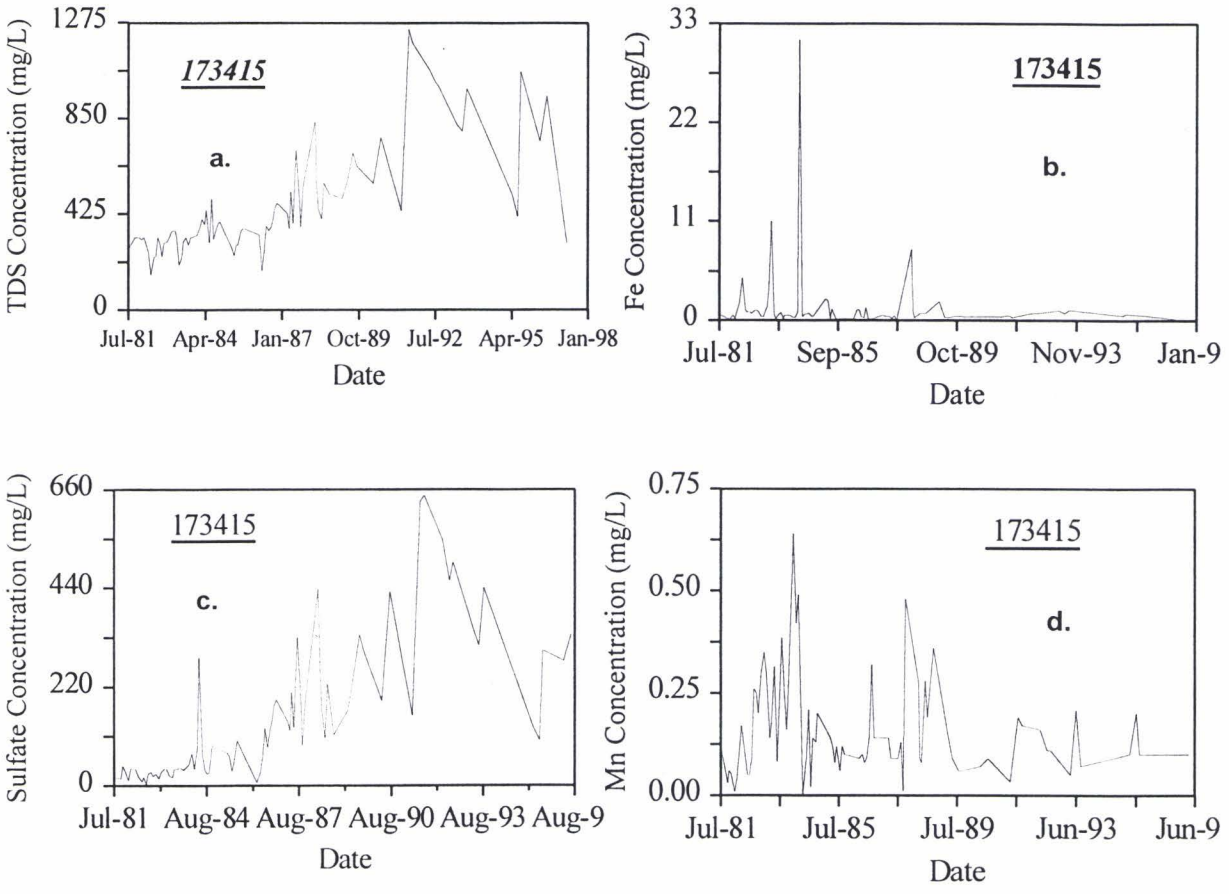


Figure 36: Time-series distributions of TDS, iron, sulfate, and manganese at Station 173415.

The next downstream station, 173428, is located after South Fork. Water quality data at this stream station are shown in Table 17 from 1981 to 1996. The data show that TDS, iron, sulfate, and manganese are the COC with TSS showing high concentrations compared to the background value given in Table 3. Also, the COC have concentrations much higher than the background values reported in Table 3. Table A13 given in Appendix A indicates that

TDS and sulfate have increasing seasonal trends whereas the others have decreasing seasonal trends with poor to modest probabilities. Figures 37a through 37d show time-series distributions of these chemicals of concern. According to Figure 37a, there is a definite increasing trend of TDS and the same can be concluded with sulfate through Figure 37c. The data in Table 17 show relatively high dissolved oxygen concentrations and no serious acid mine drainage problems. However, data on heavy metals are limited. Compared to the data of the upstream station 173415, this station also exhibited similar concentrations during the same period of 1981 through 1996. It should be noted from Table 5 that stream station 173477 in Whiskey Canyon showed alarming concentrations of TDS, TSS, iron, and manganese during 1977 through 1996. Since the concentrations between the two stations in Eccles Creek showed similar values, it can be concluded that the impact of Whiskey Creek may be minimal except it helped to maintain the high concentrations through poor quality water entering Eccles Creek.

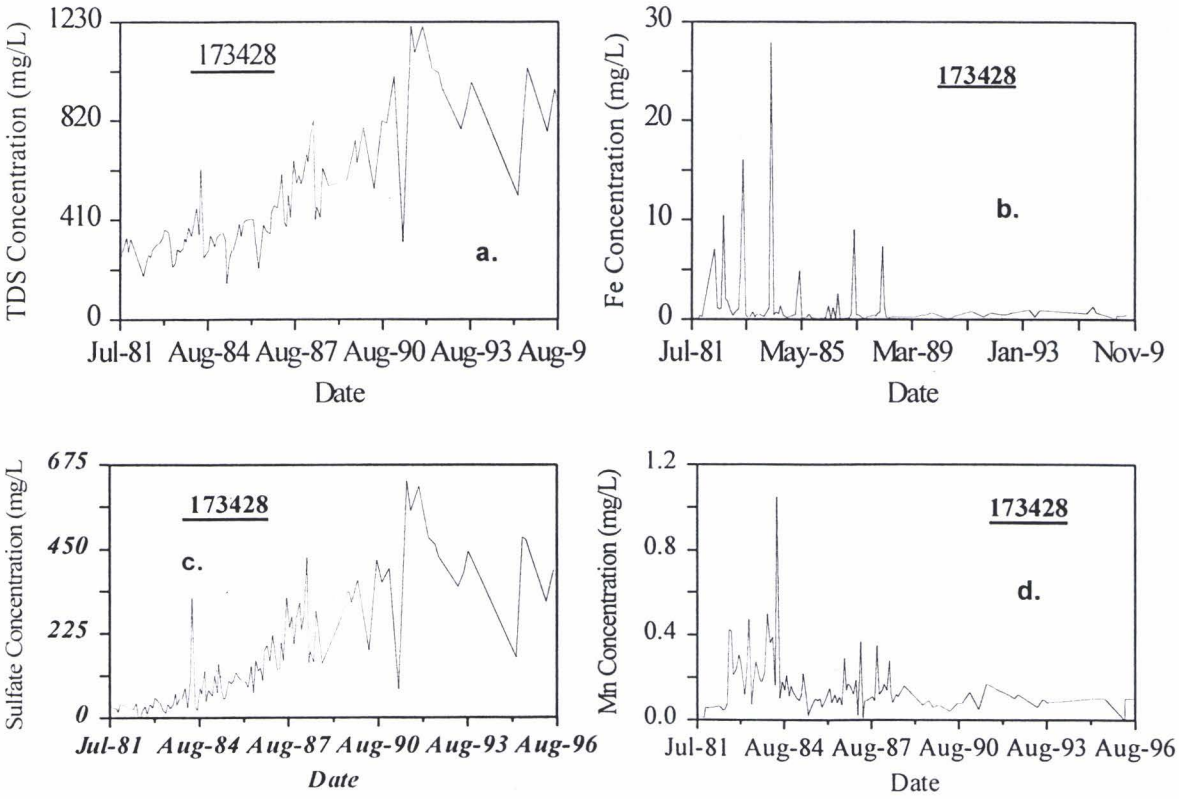


Figure 37. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173428.

The next downstream location is the USGS gaging station which has data for three years only. The summary water quality data at this station, from 1980 to 1984, are given in Table 18. The data show that TDS, iron, and manganese are the COC during these three years. However, compared to the background concentrations given in Table 3, iron may be the only concern as the others have comparable concentrations to background values. Figures 38a and 38b show the time-series distributions of iron and manganese at this location where consistent high concentration spikes are visible in 1983 for both parameters. In addition, both plots indicate a similar behavior during this period. Since the data from this station are limited compared to the other five stations, no significant conclusion can be made regarding the long-term behavior.

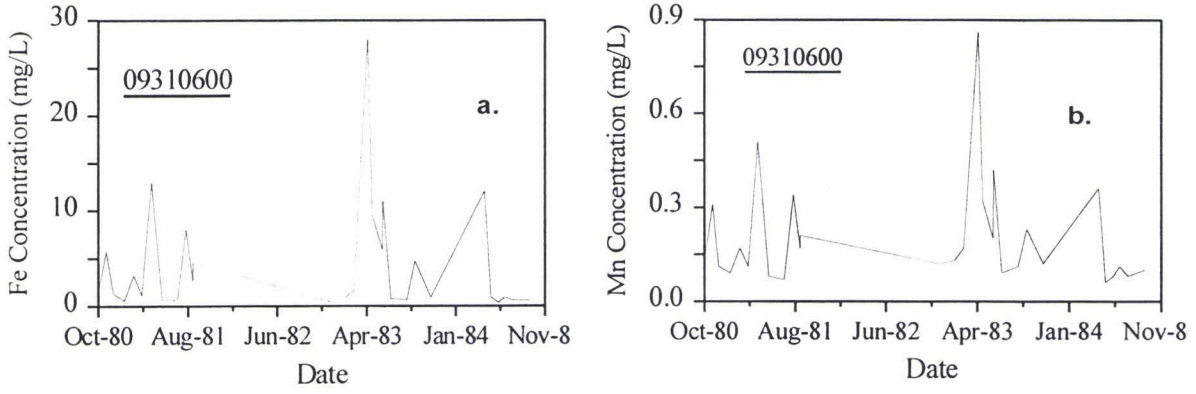


Figure 38. Time-series distributions of iron and manganese at Station 09310600.

The next stream station, 173418, is located upstream of Seep 173425. The summary water quality data are shown in Table 19 which indicate that TDS, iron, sulfate, and manganese are the COC. Also, these parameters, plus TSS, have values much higher than the background values given in Table 3. Table A14 in Appendix A indicates that TSS, iron, and manganese have decreasing seasonal trends whereas the others have increasing seasonal trends with good probability. Figures 39a through 39d show the time-series distributions of TDS, iron, sulfate, and manganese, respectively, from 1981 through 1998. TDS and sulfate show increasing trends whereas iron and manganese have decreasing trends. There is only

one data point available for each heavy metal and, therefore, the impact of heavy metals cannot be assessed. Oxygen concentration is high to maintain aerobic conditions with no immediate threat of acid mine drainage problems. The data summarized in Table 19 are similar to the previous upstream station, 173428, over the same period indicating that water quality remains a concern in Eccles Creek. Also, the impact of flow from the Whiskey Canyon plays a minor role as the concentrations were consistently high after the mine discharges.

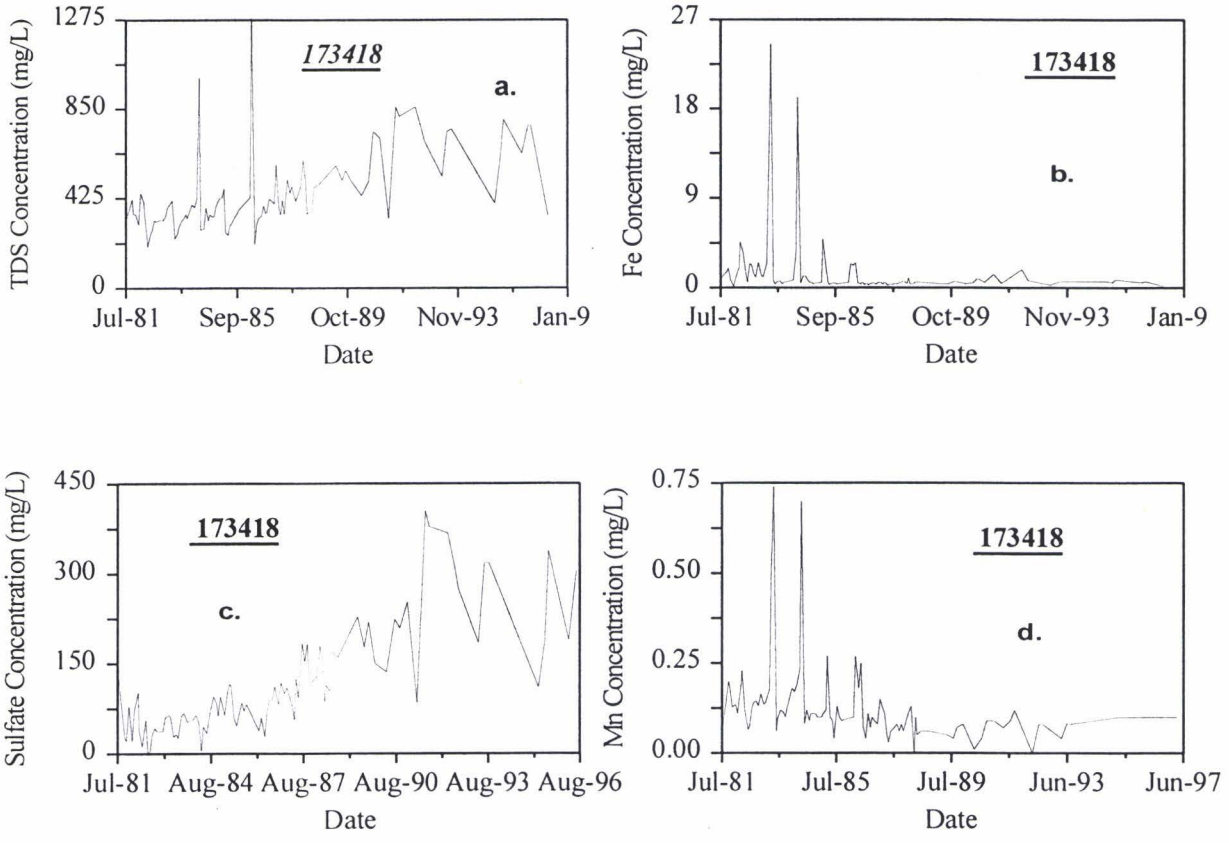


Figure 39. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173418.

The last stream station, 173452, is located slightly upstream of Mud Creek and after Seep 173425. The summary water quality data at this station are shown in Table 20. The data show that TDS, iron, sulfate, and manganese are still the COC while TSS was much higher

than the background value given in Table 3. The difference between the concentrations at this station and the previous upstream station, 173418, is minimal indicating that water quality in Eccles Creek is a concern. These observations suggest that any potential discharge from the seep had minimal impacts on the water quality of Eccles Creek. This conclusion is further evident from Table 14 where it is seen that the quality of water in this seep is much better than the existing water in Eccles Creek. Table A15 in Appendix A indicates that TSS, iron, and manganese have decreasing seasonal trends. TDS and sulfate have high increasing seasonal trends with good probability over the same period.

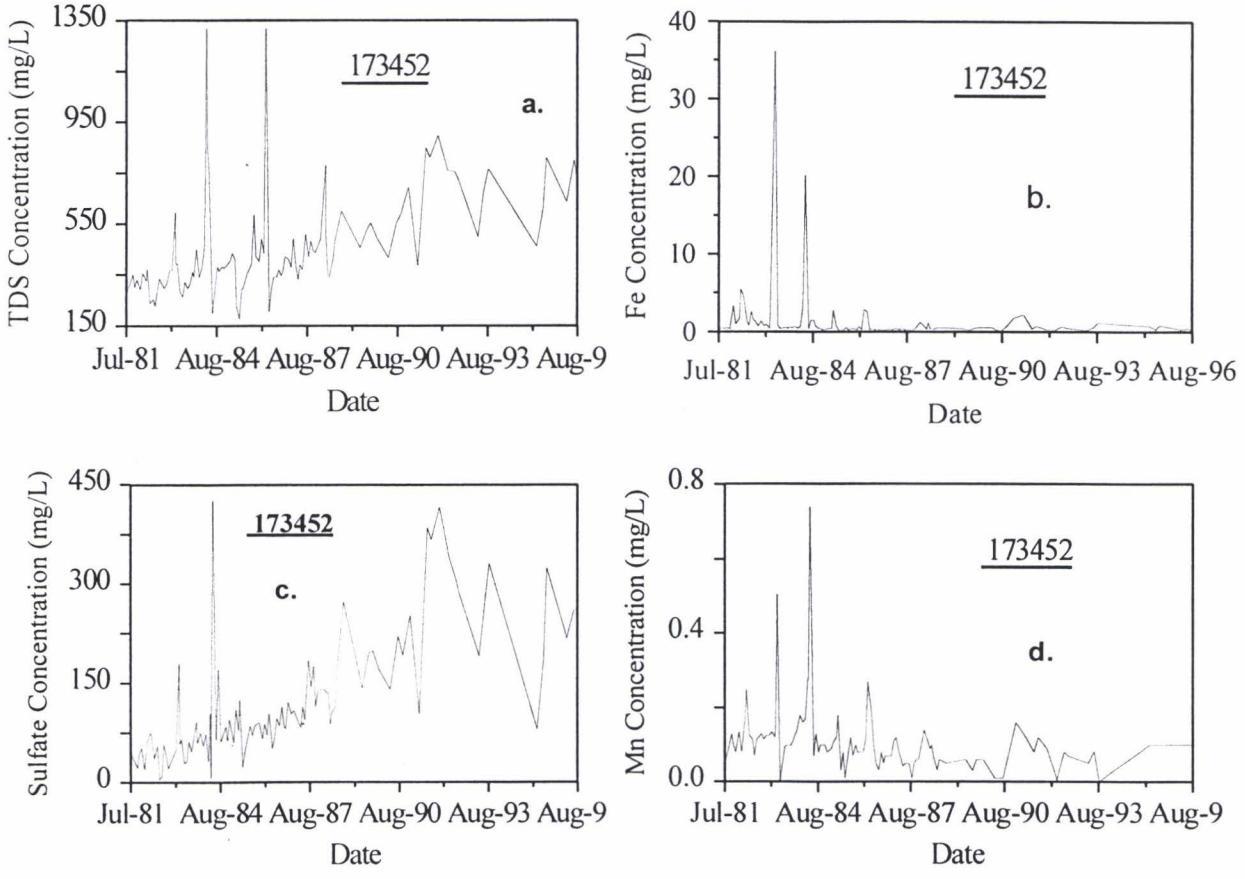


Figure 40. Time-series distributions of TDS, iron, sulfate, and manganese at Station 173452.

Figures 40a through 40d show the time-series distributions of TDS, iron, sulfate, and manganese. These plots indicate that TDS and sulfate have increasing seasonal trends whereas iron and manganese have decreasing trends. The dissolved oxygen concentration was high indicating good aerobic conditions and as in other stations, only one data point is available for heavy metals. Therefore, the impacts of heavy metals cannot be assessed. The results indicate that water quality at this stream station in Eccles Creek is a concern and may have the potential to impact the water quality of Mud Creek.

The water quality data and trend analyses from all six stream stations along Eccles Creek indicate that there are serious and consistent concerns along the entire stream reach. The common parameters of concern are TSS, TDS, iron, sulfate, and manganese, and the concerns have not diminished with flow due to dilution or any other mechanism. In fact, the water quality showed significant deterioration after the mine discharge stations located upstream of the South Fork intersection.

Water Quality of Springs

The first spring under consideration is 173431, and it is located at 8,800 feet of elevation in the Blackhawk Formation. The summary water quality data of this station are shown in Table 21 where it is seen that TDS, lead, iron, and manganese are the COC. However, only iron and TDS are elevated compared to the background values given in Table 3 whereas the other two parameters have comparable values. Table A16 in Appendix A indicates that TDS and iron have decreasing seasonal trends whereas lead has no trend. However, manganese has an increasing seasonal trend. Figures 41a through 41b show the time-series distributions of iron and manganese where the data show a clear decreasing trend for iron and an increasing trend of manganese from 1981 to 1996. Since the spring is located at a much higher location than the coal mining operations, it is safe to state that the impacts of coal mining may be insignificant except that due to subsidence causing disturbance to flow channels. The water quality may be largely controlled by water in localized saturated zones and as anticipated, the water quality of this spring is much better than that of Eccles Creek.

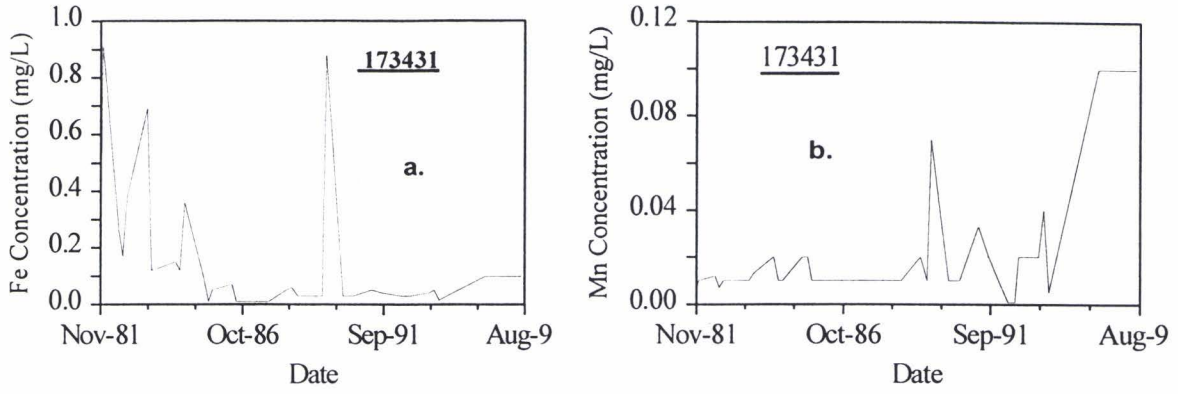


Figure 41. Time-series distributions of iron and manganese at Station 173431.

The last spring, 173435, is located at 8,080 feet of elevation in the Blackhawk Formation. This spring had consistent high flows compared to the earlier spring. The summary water quality data at this spring are given in Table 22 where TDS, lead, iron, and manganese are the COC as in the previous spring. However, this spring is located further east of the previous spring. Table A17 in Appendix A indicates that iron and manganese have increasing seasonal trends, lead has a zero trend with good probability, and TDS produced poor probability. Figures 42a and 42b show the concentrations of iron and manganese and it is seen that iron has a relatively uniform concentration pattern from 1980 to 1997 with a few downward spikes. Manganese concentrations, given in Figure 42b, show a definite increasing seasonal trend over the same period.

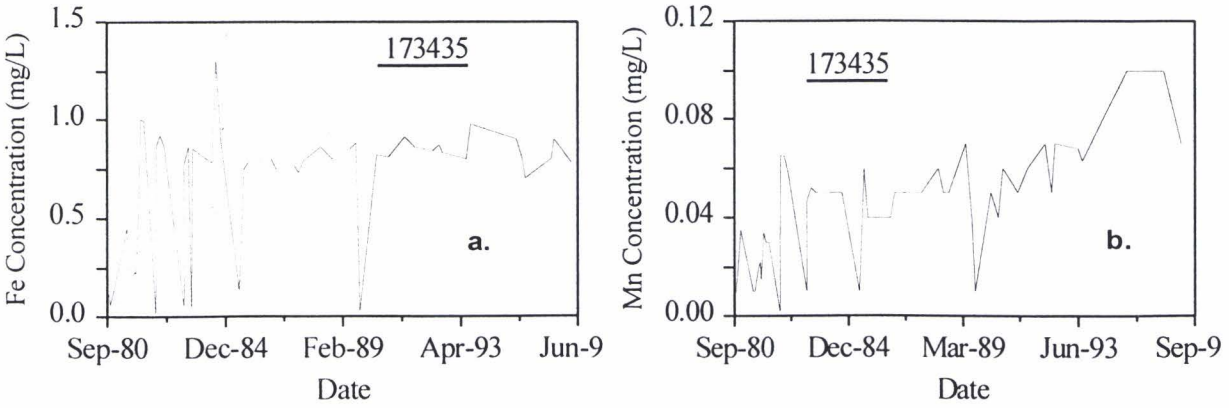


Figure 42. Time-series distributions of iron and manganese at Station 173435.

In general, the water quality data show some concerns, but they can be considered acceptable compared to the background concentrations. Any elevated concentrations reported here may be due to natural geochemical reactions between water and the formation materials or any other unknown mechanism.

4.2.5 Finns Canyon

Stream Flow

Finns Canyon flows from west to east and joins Mud Creek above the Long Canyon intersection (Figure 13). There is one stream station, 173480, available in Finns Canyon before the Mud Creek intersection. The summary flow data at this station are shown in Table 23 where flow varied from 0 to 4.2 cfs between 1980 and 1995. The highest flow occurred in Season 1 followed by Season 2, and there was no flow in Season 3. The results, given in Table A18 in Appendix A, indicate a decreasing seasonal trend during this period with good probability. The time-series flow data are shown in Figure 43a where it is seen that the flow was consistently high prior to 1985.

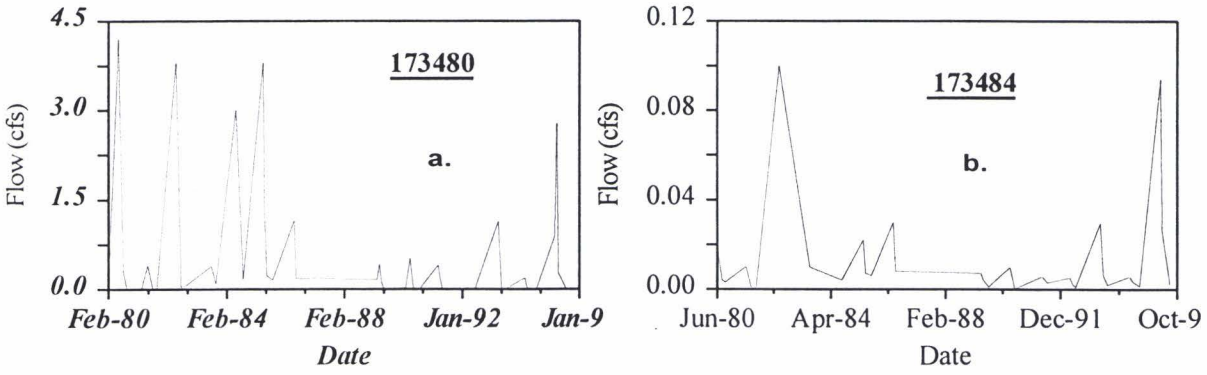


Figure 43. Time-series distributions of flow at Stations 173480 and 173484.

Spring Flow

The only spring located in the vicinity of Finns Canyon is Station 173484. This spring is located in the White Oak Mine area at an elevation of 9,480 feet in the North Horn Formation. The summary flow data at this spring are shown in Table 24 where it is seen that

Table 23. Summary water quality data at Stream Station 173480 of Finns Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	53	02/25/80-10/18/95	0	4.2	0.7711	0.0653	0	-	-
pH	**42**	**06/25/80-07/13/95**	**6.2**	**8.7**	**7.6**	**7.8**	**-**	**6.5-8.5**	**2**
TSS	41	06/25/80-07/13/95	1	228	32.5	38.2	0	-	-
TDS	42	06/25/80-07/13/95	125	354	195.9	296.3	-	500	0
Dissolved Oxygen	23	06/25/80-07/13/95	4	15.2	8.9	6.2	-	-	-
S. Cond. (µmhos/cm)	21	06/25/80-07/29/93	132	497	241	380.5	-	-	-
Chromium	4	08/25/80-05/30/91	0.001	0.01	0.01	0.004	-	0.05	0
Cadmium	**11**	**08/25/80-05/19/94**	**0.001**	**0.015**	**0.011**	**0.0055**	**-**	**0.01**	**1**
Mercury	5	08/25/80-05/30/91	0.0002	0.001	0.0002	0.0004	-	0.002	0
Arsenic	6	08/25/80-05/19/94	0.001	0.04	0.025	0.0033	-	0.05	0
Lead	**11**	**08/25/80-05/19/94**	**0.001**	**0.065**	**0.023**	**0.0055**	**-**	**0.05**	**1**
Zinc	11	08/25/80-05/19/94	0.002	0.315	0.0782	0.02	-	5	0
Iron	**28**	**06/25/80-07/13/95**	**0.02**	**8.2**	**0.7132**	**2.1**	**-**	**0.3**	**16**
Sulfate	42	06/25/80-07/13/95	0.5	89.8	20.3	28.1	-	250	0
Nitrate	11	08/25/80-05/19/94	0.01	0.314	0.201	0.0495	-	10	0
Orthophosphate	3	08/25/80-05/19/94	0.027	0.05	0.027	0.045	-	-	-
Manganese	**28**	**06/25/80-07/13/95**	**0.01**	**0.13**	**0.0312**	**0.0438**	**-**	**0.05**	**6**
Magnesium	42	06/25/80-07/13/95	2.2	58.9	15.8	23.4	-	-	-
Calcium	42	06/25/80-07/13/95	0.41	86.1	43.1	67.3	-	-	-
Bicarbonate as HCO_3^-	42	06/25/80-07/13/95	51.4	368.4	189.3	303.4	-	-	-
Total Alkalinity as $CaCO_3$	8	08/25/80-06/27/86	133.6	232	138.2	221.8	-	-	-
Total Hardness as $CaCO_3$	15	09/26/84-05/25/95	108	314	176.6	280.5	-	-	-

Table 24. Summary water quality data at Spring 173484 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	35	06/25/80-10/18/95	0.0003	0.1	0.0157	0.0088	-	-	-
pH	**35**	**06/25/80-10/18/95**	**6.6**	**8.5**	**7.3**	**7.5**	**-**	**6.5-8.5**	**0**
TSS	3	06/25/80-10/08/80	1	8	1	5	-	-	-
TDS	35	06/25/80-10/18/95	152	345	242	286	-	500	0
S. Cond. (µmhos/cm)	20	06/25/80-10/11/95	190	491	329	364	-	-	-
Chromium	4	08/27/80-09/19/91	0.001	0.01	-	0.0055	-	0.05	0
Cadmium	13	08/27/80-10/18/95	0.001	0.01	0.01	0.0064	-	0.01	0
Mercury	5	08/27/80-09/19/91	0.0002	0.0002	-	0.0002	-	0.002	0
Arsenic	9	08/27/80-10/18/95	0.001	0.04	0.025	0.0119	-	0.05	-
Lead	**14**	**08/27/80-10/18/95**	**0.001**	**0.17**	**0.012**	**0.0249**	**-**	**0.05**	**1**
Zinc	13	08/27/80-10/18/95	0.005	0.045	0.0117	0.0216	-	5	0
Iron	**17**	**06/25/80-10/18/95**	**0.01**	**0.521**	**0.0753**	**0.1089**	**-**	**0.3**	**1**
Sulfate	34	06/25/80-10/18/95	0.1	61.8	22.1	25.4	-	250	0
Nitrate	13	08/27/80-10/18/95	0.01	1.25	0.5788	0.4924	-	10	0
Orthophosphate	7	08/27/80-06/16/94	0.01	0.05	0.011	0.0203	-	-	-
Manganese	27	06/25/80-10/18/95	0.001	0.019	0.0092	0.0093	-	0.05	0
Magnesium	35	06/25/80-10/18/95	1.44	34.2	16.4	18.7	-	-	-
Calcium	35	06/25/80-10/18/95	38.3	98.8	61.7	71.8	-	-	-
Bicarbonate as HCO_3^-	35	06/25/80-10/18/95	158.6	315	236.8	285.2	-	-	-
Total Alkalinity as $CaCO_3$	6	08/27/80-06/27/86	144	233.1	180	219.8	-	-	-
Total Hardness as $CaCO_3$	19	09/26/84-10/18/95	167	289	208.1	263	-	-	-

flow varied from 0.0003 to 0.1 cfs between 1980 and 1995. The results, given in Table A19 in Appendix A, indicate zero trend of flow during this period. This observation is also reflected in the time-series flow data shown in Figure 43b.

Water Quality of Finns Canyon

Since the only available monitoring station is located upstream of the Mud Creek intersection, the water quality data at this station reflect the potential impacts on Mud Creek. The summary water quality data at this station, 173480, are given in Table 23. The data show that cadmium, lead, iron, and manganese are the COC. However, the impacts of cadmium, manganese, and lead can be disregarded as the concentrations are comparable to background values given in Table 3 or MCL in the case of cadmium; for example, the maximum cadmium, lead, and manganese concentrations were 0.015, 0.065, and 0.13 mg/L, respectively. However, the iron concentration of 8.2 mg/L is relatively higher than the background value and exceeded the MCL 16 times. The trend results, given in Table A18, in Appendix A indicate that lead has an increasing seasonal trend with good probability and the other parameters produced poor probability. The oxygen concentration was high in the stream at all times, and the pH data did not indicate serious acid mine drainage problems. Therefore, the water quality data indicate minimal concerns at this stream section and also negligible impacts to Mud Creek.

Water Quality of Spring

The summary water quality data at Spring 173484, are given in Table 24 where it is seen that lead and iron are the only COC. However, the concentrations exceeded MCLs once, and the reported maximum concentrations of 0.17 and 0.521 mg/L are comparable to background values. Therefore, the water quality data indicate negligible concerns at this spring.

4.2.6 Boardinghouse Canyon

Boardinghouse Canyon flows parallel to Finns Canyon and downstream of Mud Creek from the Finns Canyon intersection (Figure 13). There are two stream monitoring stations along

Boardinghouse Canyon, one monitored by the White Oak Mine (173479) and the other by the USGS (09310575). There is a spring (173486) located upstream of Boardinghouse Canyon.

Stream Flow

The summary water flow data from the upstream station, 173479, are shown in Table 25. It should be noted that this station is located upstream of the USGS station. The data show a flow variation of 0.058 to 12.8 cfs between 1980 and 1995. This flow range is much higher than the flow in Finns Canyon which was only 0 to 4.2 cfs over the same period. The results in Table A20 in Appendix A indicate a decreasing seasonal trend of flow at this station. This observation is further supported by the time-series data given in Figure 44a. High flows were evident at this station around 1984. Since the flow is substantially higher than that of Finns Canyon, it can be concluded that the flow contribution to Mud Creek from Boardinghouse Canyon is important. The decreasing seasonal trend of flow at this station may be a concern to water users as well as to the flow of Mud Creek.

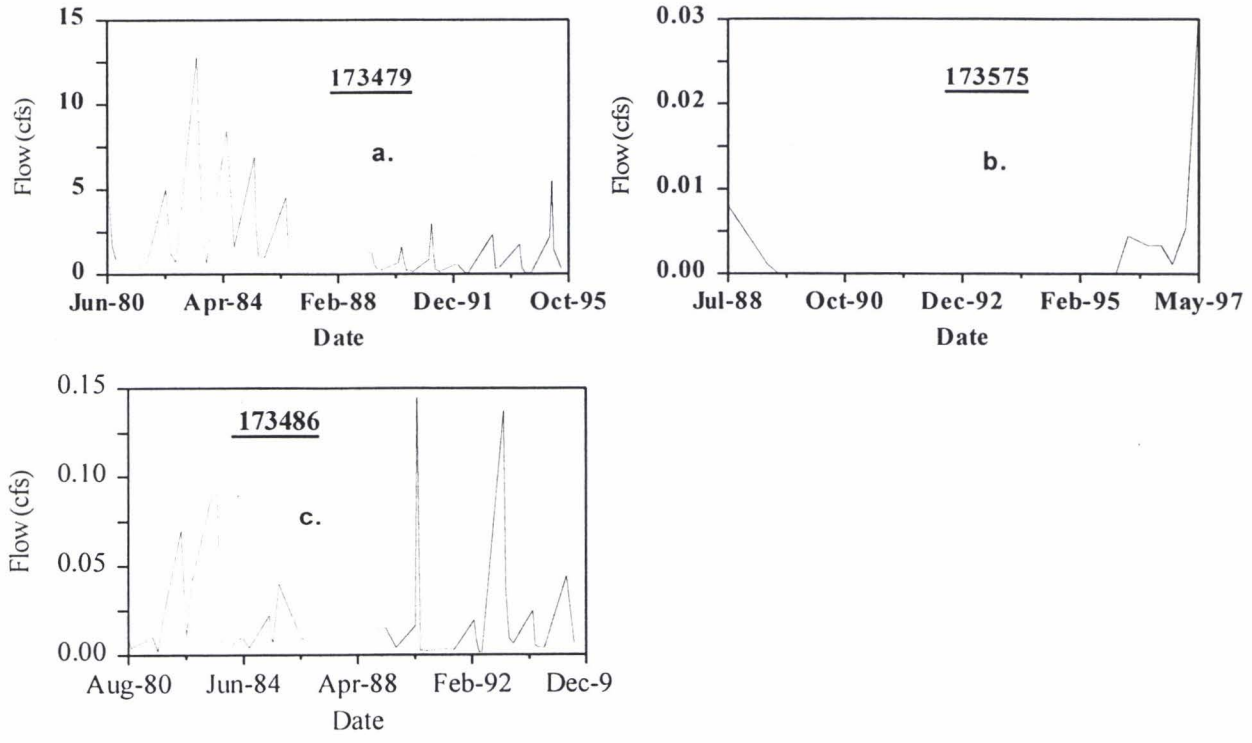


Figure 44. Time-series distributions of flow at Stations 173479, 173575, and 173486.

Table 25. Summary water quality data at Stream Station 173479 of Boardinghouse Canyon in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	52	06/25/80-10/18/95	0.058	12.8	2.3	0.7098	-	-	-
pH	**52**	**06/25/80-10/18/95**	**6.2**	**8.8**	**7.6**	**7.7**	**7.9**	**6.5-8.5**	**1**
TSS	51	06/25/80-10/18/95	1.6	201	25	32.1	26	-	-
TDS	53	06/25/80-10/18/95	47	459	209	279.6	295	500	0
Dissolved Oxygen	31	06/25/80-10/18/95	5.8	16	9.9	9.5	-	-	-
S. Cond. (µmhos/cm)	28	06/25/80-10/18/95	132	522	284.4	390.6	260	-	-
Chromium	7	08/25/80-09/10/91	0.001	0.01	0.01	0.004	-	0.05	0
Cadmium	15	08/25/80-10/18/95	0.001	0.01	0.01	0.0054	-	0.01	0
Mercury	7	08/25/80-09/10/91	0.0002	0.0002	0.0002	0.0002	-	0.002	0
Arsenic	10	08/25/80-10/18/95	0.001	0.04	0.025	0.007	-	0.05	0
Lead	15	08/25/80-10/18/95	0.001	0.03	0.016	0.0059	-	0.05	0
Zinc	15	08/25/80-10/18/95	0.002	0.255	0.0738	0.0185	-	5	0
Iron	**37**	**06/25/80-10/18/95**	**0.01**	**2.1**	**0.5507**	**0.5056**	**0.025**	**0.3**	**23**
Sulfate	53	06/25/80-10/18/95	0.5	130	24.6	24.1	32	250	0
Nitrate	15	08/25/80-10/18/95	0.01	0.372	0.199	0.0733	-	10	0
Orthophosphate	4	08/25/80-05/19/94	0.006	0.09	0.026	0.052	-	-	-
Manganese	**37**	**06/25/80-10/18/95**	**0.009**	**0.095**	**0.0288**	**0.0292**	**0.009**	**0.05**	**4**
Magnesium	54	06/25/80-10/18/95	5	47.9	17	22.6	23	-	-
Calcium	54	06/25/80-10/18/95	32.8	90	49.8	63.4	77.5	-	-
Bicarbonate as HCO_3^-	54	06/25/80-10/18/95	89	328.2	203.9	292.8	304.8	-	-
Total Alkalinity as $CaCO_3$	10	08/25/80-06/28/86	146	249.8	163.8	231.9	249.8	-	-
Total Hardness as $CaCO_3$	21	09/26/84-10/18/95	101	288	178.7	261.8	-	-	-

The next downstream station is Station 09310575 monitored by the USGS. However, the data from this station are limited and available for less than one year only. The summary water flow data from May 1984 to September 1984 are shown in Table 26. The data show that the flow varied from 0.23 to 11 cfs during these four months. Since the data are spanned over four months of 1984, the mean values computed for different seasons may not be reliable and should be interpreted carefully. The time-series distribution of flow data is given in Figure 44b which indicates a sharp increasing trend until August 1984 followed by an immediate decline, probably due to the end of the snowmelt period. Compared to the water flow data from the upstream station, this location had a small period of reported data. Therefore, the data from this station cannot be used to predict the long-term behavior of flow in Boardinghouse Canyon in conjunction with the upstream station.

Spring Flow

Spring 173486 is located at 9,360 feet of elevation in the North Horn Formation of the White Oak Mine area. The summary water flow data at this spring are given in Table 27 where it is seen that flow varied from 0.0014 to 0.145 cfs between 1980 and 1995. Compared to Spring 173484 which is located further away, this spring has slightly higher flow. The results, given in Table A21 in Appendix A, indicate zero trend of flow during this period with poor probability. The time-series data shown in Figure 44c indicate the presence of high flow spikes prior to 1984 and after 1988. The data from this spring, including the seasonal means, indicate that flow is relatively uniform and has not been affected over the past 15 years.

Water Quality of Boardinghouse Canyon

The summary water quality data at the upstream station, 1734479, are given in Table 25. The data show that during 1980 to 1995, the only COC were iron and manganese. However, compared to the background values given in Table 3, it can be concluded that iron may be the only COC. The results in Table A20 of Appendix A indicate that iron has a decreasing seasonal trend whereas manganese has an increasing seasonal trend. Figures 45a and 45b show the iron and manganese concentrations where it is seen that iron concentrations peaked to more than 2 mg/L in 1983. The dissolved oxygen concentration was high indicating good

Table 26. Summary water quality data at Stream Station 09310575 of Boardinghouse Canyon in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	29	5/23/84-9/21/84	0.23	11	0.23	3.61	-	-	-
pH	**14**	**2/15/83-10/24/84**	**7.1**	**8.6**	**7.9**	**8.2**	**8.2**	**6.5-8.5**	**2**
TDS	18	12/9/82-10/24/84	155	312	223	274	272	500	-
Dissolved Oxygen	12	2/15/83-10/24/84	8.1	9.9	8.6	9	9.9	-	-
S. Cond. (µmhos/cm)	21	12/9/82-10/24/84	235	560	377	499	503	-	-
Cadmium	9	4/18/83-10/24/84	0.001	0.001	0.001	0.001	-	0.01	-
Lead	9	4/18/83-10/24/84	0.001	0.016	0.0082	0.0012	-	0.05	-
Zinc	9	4/18/83-10/24/84	0.01	0.07	0.04	0.018	-	5	-
Iron	**18**	**12/9/82-10/24/84**	**0.13**	**13**	**4.8**	**0.31**	**0.265**	**0.3**	**11**
Manganese	**18**	**12/9/82-10/24/84**	**0.02**	**0.5**	**0.1813**	**0.025**	**0.0225**	**0.05**	**4**
Total Hardness as $CaCO_3$	11	6/10/83-8/28/84	140	290	182	278	280	-	-

Table 27. Summary water quality data at Spring 173486 in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	44	08/27/80-10/18/95	0.0014	0.145	0.0282	0.0143	-	-	-
pH	**44**	**08/27/80-10/18/95**	**5.9**	**8.6**	**7.5**	**7.7**	-	**6.5-8.5**	**1**
TSS	2	08/27/80-10/08/80	3	5	-	4	-	-	-
TDS	45	08/27/80-10/18/95	172	298	233.8	241.5	-	500	0
S. Cond. (µmhos/cm)	25	08/27/80-10/18/95	212	491	327.8	338.2	-	-	-
Chromium	3	10/11/90-05/26/92	0.01	0.011	0.011	0.01	-	0.05	0
Cadmium	17	08/27/80-10/18/95	0.001	0.01	0.01	0.0063	-	0.01	0
Mercury	7	08/27/80-05/26/92	0.0002	0.0005	0.0005	0.0002	-	0.002	0
Arsenic	12	08/27/80-10/18/95	0.001	0.05	0.0433	0.0139	-	0.05	0
Lead	**17**	**08/27/80-10/18/95**	**0.001**	**0.07**	**0.017**	**0.0123**	-	**0.05**	**1**
Zinc	17	08/27/80-10/18/95	0.007	0.08	0.0392	0.0181	-	5	0
Iron	**22**	**08/27/80-10/18/95**	**0.05**	**2**	**0.443**	**0.3571**	-	**0.3**	**8**
Sulfate	44	08/27/80-10/18/95	0.1	52.8	10	7.7	-	250	0
Nitrate	17	08/27/80-10/18/95	0.01	2.2	0.33	0.6982	-	10	0
Orthophosphate	10	08/27/80-05/19/94	0.005	0.158	0.0396	0.032	-	-	-
Manganese	**33**	**08/27/80-10/18/95**	**0.001**	**0.399**	**0.04**	**0.0202**	-	**0.05**	**4**
Magnesium	45	08/27/80-10/18/95	6	29.2	13	13.6	-	-	-
Calcium	45	08/27/80-10/18/95	44.8	138	65.9	68	-	-	-
Bicarbonate as HCO_3^-	45	08/27/80-10/18/95	121	311.2	247.2	247.3	-	-	-
Total Alkalinity as $CaCO_3$	9	08/27/80-06/27/86	199	255.1	211.1	231.5	-	-	-
Total Hardness as $CaCO_3$	19	09/26/84-10/18/95	160	265	215.2	226.2	-	-	-

aerobic conditions, and pH values are marginally outside the acceptable range. Based on the water quality data shown in Table 25, it can be concluded that there are no serious concerns at this stream station.

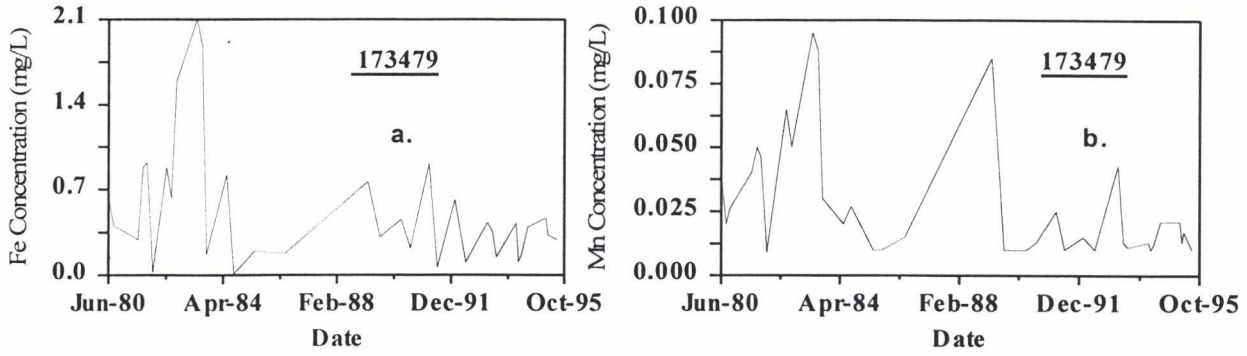


Figure 45. Time-series distributions of iron and manganese at Station 173479.

The summary flow data at the next downstream station, 09310575, are given in Table 26. The data show that iron and manganese concentrations were high at this station during 1984. However, compared to the background values given in Table 3, manganese can be disregarded as a potential threat to water quality. However, iron concentrations were too high, around 13 mg/L. The time-series distributions of iron and manganese are given in Figures 46a and 46b. Both plots show similar behaviors between the two parameters with peaks around June 1983 and May 1984. At other times, the concentrations were relatively small and were comparable to background values.

Water Quality of Spring

The summary water quality data at Spring 173486 are given in Table 27. The data indicate the presence of lead, iron, and manganese as the COC. Again, compared to the background values given in Table 3, it can be concluded that iron and manganese may be the only concerns. Figures 47a and 47b show the time-series distributions of iron and manganese at this spring. The data clearly indicate an increasing trend of iron and to a smaller degree by manganese. The results given in Table A21 in Appendix A further confirm this observation.

There are no reported data on dissolved oxygen, and data on heavy metals were limited. In summary, it can be concluded that the overall quality of water is acceptable. Any elevated concentrations of iron and manganese may be due to natural geochemical reactions between water and the formation materials rather than due to any obvious coal mining operations or other land uses.

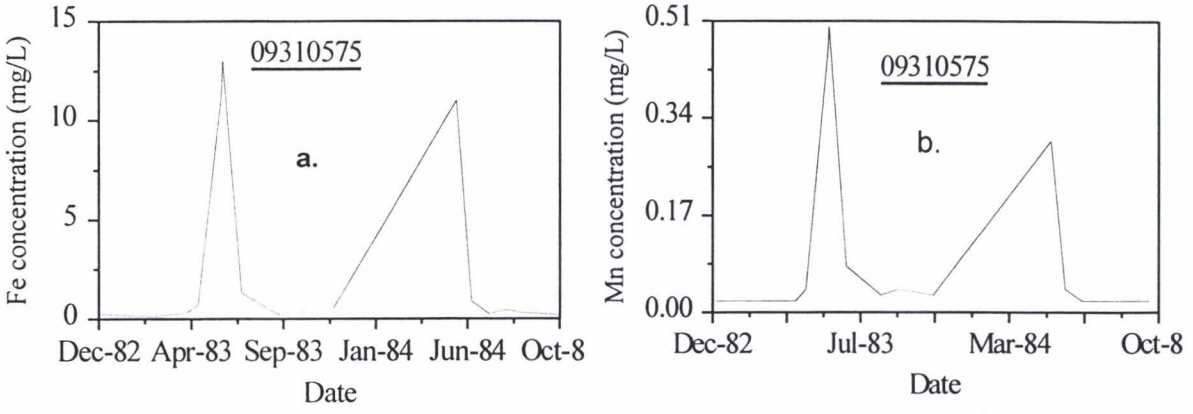


Figure 46. Time-series distributions of iron and manganese at Station 09310575.

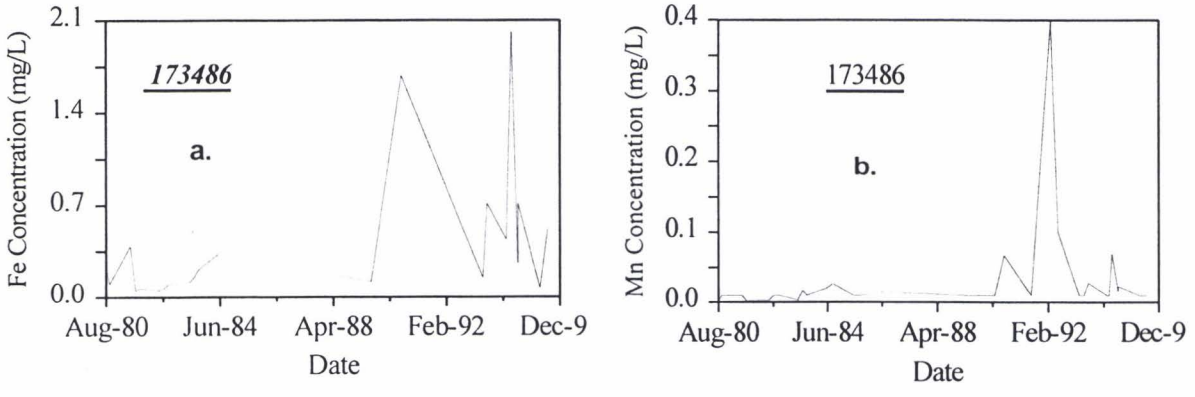


Figure 47. Time-series distributions of iron and manganese at Station 173486.

4.2.7 Mud Creek

Mud Creek is the recipient of flows from major tributaries including Finns Canyon, Boardinghouse Canyon, and Eccles Creek, and eventually discharges to Scofield Reservoir (Figures 13 and 14). There are three stream stations, one mine discharge, and one ground water well selected for the final analysis.

Mine Discharge

The UPDES station, 173449, is discharging water to Eccles Creek near the intersection with Mud Creek. As this location is close to the Mud Creek intersection, this UPDES station data will be analyzed in this section. The summary water flow data at this station are given in Table 28 where the flow varied from 0 to 0.334 cfs between 1982 and 1996. It is also seen that the means of Seasons 1 and 2 were almost the same at approximately 0.02 cfs whereas the mean of Season 3 reduced by 50%. The results, given in Table A22 in Appendix A, indicate a decreasing seasonal trend with good probability. The time-series flow data given in Figure 48a further confirms this conclusion. The data from this station suggest that flow has been decreasing at this station from 1982 to 1996.

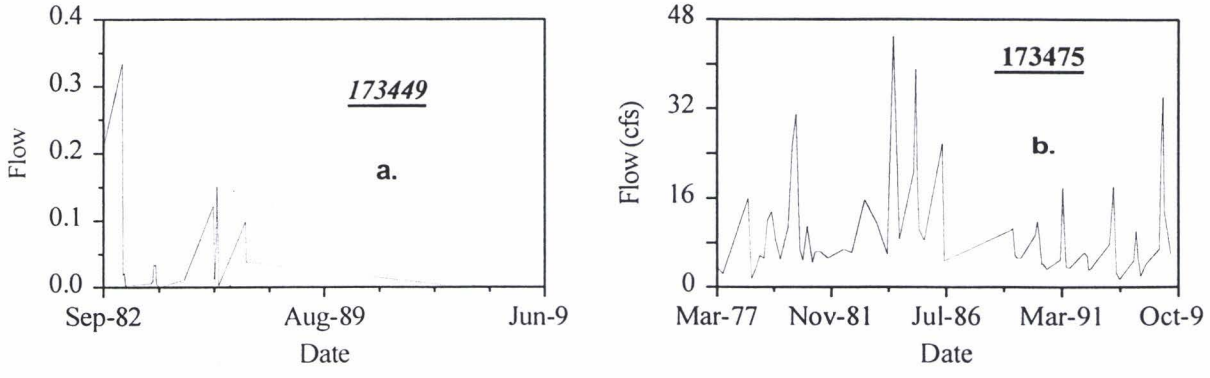


Table 28. Summary water quality data at UPDES Discharge Station 173449 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	52	09/30/82-06/00/96	0	0.3341	0.0269	0.0298	0.0153	-	-
pH	**14**	**03/22/84-03/18/87**	**6.7**	**8.8**	**8.3**	**7.7**	**7.2**	**6.5-8.5**	**3**
TSS	22	09/30/82-08/23/87	1	168	31.1	13.5	9.4	-	-
TDS	**28**	**09/30/82-08/23/87**	**120**	**718**	**272.2**	**384.5**	**364**	**500**	**4**
S. Cond. (µmhos/cm)	14	03/22/84-03/18/87	298	1080	438.9	381	605.2	-	-
Chromium	1	09/30/82	0.001	0.001	-	0.001	-	0.05	0
Cadmium	1	09/30/82	0.001	0.001	-	0.001	-	0.01	0
Mercury	1	09/30/82	0.0002	0.0002	-	0.0002	-	0.002	0
Arsenic	1	09/30/82	0.001	0.001	-	0.001	-	0.05	0
Lead	1	09/30/82	0.003	0.003	-	0.003	-	0.05	0
Zinc	1	09/30/82	0.022	0.022	-	0.022	-	5	0
Iron	**27**	**09/30/82-08/23/87**	**0.02**	**3.2**	**0.8788**	**0.585**	**0.7383**	**0.3**	**17**
Sulfate	1	09/30/82	6	6	-	6	-	250	0
Nitrate	1	09/30/82	0.84	0.84	-	0.84	-	10	0
Manganese	1	09/30/82	0.03	0.03	-	0.03	-	0.05	0
Magnesium	1	09/30/82	12.5	12.5	-	12.5	-	-	-
Total Alkalinity as $CaCO_3$	1	09/30/82	37.9	37.9	-	37.9	-	-	-

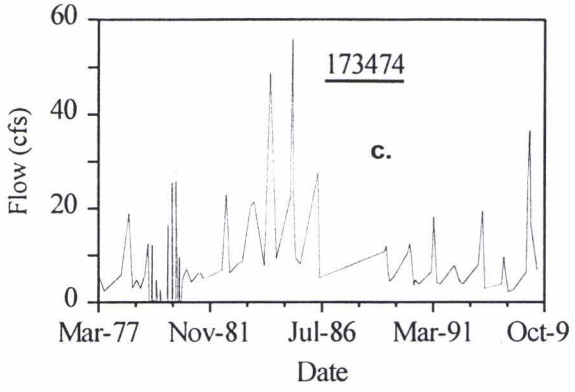


Figure 48. Time-series distributions of flow at Stations 173449, 173475, and 173474.

Stream Flow

The first stream station in Mud Creek, 173475, is located between Eccles Creek and Green Canyon (Figure 13). The summary water flow data at this station are given in Table 29 where the flow varied between 1.33 and 45 cfs from 1977 to 1995. The seasonal means were 12.5, 5.3, and 6.6 for Seasons 1, 2, and 3, respectively. The data suggest that the maximum observed flow at this station is substantial, and peak flows occurred during spring to early summer months. Table A23 in Appendix A shows that flow decreased at 0.283 cfs per year with good probability during 1977 to 1995. Figure 48b shows the time-series distribution of flow at this station where peak flows occurred prior to 1981, between 1984 and 1986, and towards 1995. The maximum flow of Eccles Creek during similar periods was 13.7 cfs at Station 173452 indicating that a major portion of flow to Mud Creek was from Eccles Creek. Therefore, as discussed earlier, Eccles Creek plays an important role in controlling the flow of Mud Creek.

The next stream station, 173474, is located downstream of the Green Canyon intersection and therefore, the contributions of Green Canyon together with other tributaries are important to assess the flow at this station. However, there are no stream stations located in these tributaries. The summary flow data at this stream station are shown in Table 30. The flow varied from 0 to 55.9 cfs during 1977 to 1995 with a mean of Season 1 of 10.4 cfs.

Table 29. Summary water quality data at Stream Station 173475 of Mud Creek in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	70	03/17/77-10/18/95	1.33	45	12.5	5.3	6.6	-	-
pH	**81**	**03/17/77-10/18/95**	**6.6**	**9.2**	**7.8**	**7.8**	**7.9**	**6.5-8.5**	**8**
TSS	**80**	**03/17/77-10/18/95**	**1**	**14025**	**147.4**	**668**	**38.4**	**-**	**-**
TDS	**81**	**03/17/77-10/18/95**	**160**	**779**	**368.5**	**390.3**	**391.8**	**500**	**15**
Dissolved Oxygen	46	03/17/77-10/18/95	6	18	9.8	10	10	-	-
S. Cond. (µmhos/cm)	51	03/17/77-10/18/95	200	1104	406.2	536.9	505.4	-	-
Chromium	7	08/26/81-09/10/91	0.001	0.01	0.01	0.0046	-	0.05	0
Cadmium	30	03/17/77-10/18/95	0.001	0.01	0.0067	0.0042	0.001	0.01	0
Mercury	21	03/17/77-0910/91	0.0002	0.0002	0.0002	0.0002	0.0002	0.002	0
Arsenic	24	03/17/77-10/18/95	0.001	0.02	0.0057	0.0049	0.001	0.05	0
Lead	30	03/17/77-10/18/95	0.001	0.9	0.0877	0.0046	0.005	0.05	1
Zinc	30	03/17/77-10/18/95	0.001	0.252	0.041	0.0124	0.0096	5	0
Iron	**63**	**03/17/77-10/18/95**	**0.075**	**72.8**	**3.9**	**0.7828**	**0.9452**	**0.3**	**48**
Sulfate	81	03/17/77-10/18/95	3	268	86.1	8.9	53.8	250	2
Nitrate	27	03/17/77-10/18/95	0.01	0.48	0.1915	0.1218	0.0825	10	0
Orthophosphate	11	03/17/77-10/13/82	0.001	0.14	0.0337	0.0622	0.0767	-	-
Manganese	**63**	**03/17/77-10/18/95**	**0.001**	**6.5**	**0.1273**	**0.3578**	**0.0822**	**0.05**	**38**
Magnesium	81	03/17/77-10/18/95	9.5	120	27.4	31	34.6	-	-
Calcium	81	03/17/77-10/18/95	16.4	102	63.8	70.1	70.6	-	-
Bicarbonate as HCO_3^-	81	03/17/77-10/18/95	152	377	250.2	289.4	302.7	-	-
Total Alkalinity as $CaCO_3$	21	03/17/77-06/27/86	147	297.4	218.9	227.1	253.3	-	-
Total Hardness as $CaCO_3$	23	03/17/77-10/18/95	196	454	299.8	363.3	280	-	-

Table 30. Summary water quality data at Stream Station 173474 of Mud Creek in the Price River Watershed obtained from the White Oak Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	107	03/17/77-10/18/95	0	55.9	10.4	5.2	3.4	-	-
pH	**101**	**03/17/77-10/18/95**	**6.4**	**8.9**	**7.8**	**7.7**	**7.8**	**6.5-8.5**	**8**
TSS	**100**	**03/17/77-10/18/95**	**1**	**6460**	**134.6**	**232.8**	**63.3**	-	-
TDS	**102**	**03/17/77-10/18/95**	**156**	**1202**	**360.3**	**387.9**	**366**	**500**	**17**
Dissolved Oxygen	50	03/17/77-10/18/95	4.6	17	9.8	9.7	10.1	-	-
S. Cond. (µmhos/cm)	52	03/17/77-10/18/95	211	1034	411.9	530	495	-	-
Chromium	8	02/28/79-09/10/91	0.001	0.01	0.01	0.0046	0.001	0.05	0
Cadmium	31	03/17/77-10/18/95	0.001	0.02	0.0067	0.0049	0.0012	0.01	1
Mercury	22	03/17/77-09/10/91	0.0002	0.002	0.0002	0.0004	0.0002	0.002	0
Arsenic	25	03/17/77-10/18/95	0.001	0.02	0.0049	0.0052	0.001	0.05	0
Lead	32	03/17/77-10/18/95	0.001	0.06	0.0069	0.0046	0.011	0.05	1
Zinc	31	03/17/77-10/18/95	0.004	0.188	0.029	0.0151	0.0105	5	0
Iron	**84**	**03/17/77-10/18/95**	**0.015**	**402**	**11.8**	**0.7036**	**1.3**	**0.3**	**56**
Sulfate	**82**	**03/17/77-10/18/95**	**4.2**	**370**	**86.9**	**100**	**70.5**	**250**	**5**
Nitrate	28	03/17/77-10/18/95	0.01	0.42	0.1239	0.1014	0.088	10	0
Orthophosphate	12	03/17/77-10/13/82	0.01	0.19	0.0717	0.08	0.1012	-	-
Manganese	**77**	**03/17/77-10/18/95**	**0.001**	**2.1**	**0.1329**	**0.1247**	**0.0917**	**0.05**	**36**
Magnesium	82	03/17/77-10/18/95	4.3	120	27.2	31.8	34.5	-	-
Calcium	82	03/17/77-10/18/95	13.2	99.6	63.2	68.0	69.6	-	-
Bicarbonate as HCO_3^-	82	03/17/77-10/18/95	157	366.5	248.6	287.4	302.1	-	-
Total Alkalinity as $CaCO_3$	43	03/17/77-04/21/93	139	362	216.1	221.3	242.7	-	-
Total Hardness as $CaCO_3$	23	03/17/77-10/18/95	201	454	301.4	354	282	-	-

Table A24 in Appendix A shows a high increasing seasonal trend of 0.34 cfs per year at this station. The time-series flow data at this station are shown in Figure 48c where it is seen that the peak flow of 55.9 cfs occurred in the summer of 1985.

The downstream monitoring location of Mud Creek is the USGS station 09310700 which has flow data for one month only. The flow data are shown in Table 31 and flow varied from 11 to 38 cfs within one month. Due to the limited availability of data at this station, the means computed for different seasons may not be accurate and should be disregarded.

The data from the two stream stations monitored by White Oak Mine indicate that the upstream of Mud Creek after Eccles Creek showed a substantial loss of flow. However, this loss was corrected through contributions from other downstream tributaries, runoff, and base flow such that downstream locations showed a strong increasing trend of flow. Therefore, based on the data from these two stations only, it can be concluded that this reach of Mud Creek did not exhibit serious water losses during 1977 to 1995. Therefore, the contribution of discharge to Scofield Reservoir from this reach may not have been affected during this period.

Figure 49 shows the time-series distribution of discharge from Scofield Reservoir to Price River between 1974 and 1997. The data were obtained from the Bureau of Reclamation. The data indicate a relatively uniform discharge from 1974 to 1984 and again after 1986. However, the discharge increased substantially from 1984 to 1986; for example, the discharge was close to 1200 cfs in 1983. A possible reason for this high discharge may be the high water demand from downstream users of the Price River due to less recharge during this period or changes in land-use pattern causing higher than the usual demand. Also, it should be noted that discharge flow rates are substantially higher than the maximum flow of Mud Creek which was around 60 cfs at Station 173474. The average discharge flow from 1974 to 1997 was around 200 cfs. Therefore, it can be approximated that Mud Creek may be providing 25% or less of the discharge from Scofield Reservoir to the Price River. Hence, other tributaries may be playing an important role in contributing flow to the reservoir.

Table 31. Summary water quality data at Stream Station 09310700 of Mud Creek in the Price River Watershed obtained from USGS. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	40	8/19/84-9/21/84	11	38	-	18.5	-	-	-
pH	**54**	**8/14/78-10/24/84**	**7.6**	**8.6**	**8.2**	**8.4**	**8.2**	**6.5-8.5**	**3**
TDS	28	10/16/80-10/24/84	162	361	260	301	342	500	-
Dissolved Oxygen	51	8/14/78-10/24/84	7	12	9	8.6	10.5	-	-
S. Cond. (µmhos/cm)	94	8/14/78-8/7/91	255	1050	436	537	609	-	-
Iron	**27**	**10/16/80-10/24/84**	**0.22**	**20**	**3.8**	**0.8833**	**1.2**	**0.3**	**25**
Orthophosphate	17	9/19/78-3/2/83	0	0	0	0	0	-	-
Manganese	**27**	**10/16/80-10/24/84**	**0.02**	**0.49**	**0.1389**	**0.0722**	**0.0844**	**0.05**	**17**
Bicarbonate as HCO_3^-	37	8/14/78-9/2/81	170	360	239	273	314	-	-
Total Alkalinity as $CaCO_3$	43	8/14/78-9/2/81	139	350	194	240	258	-	-
Total Hardness as $CaCO_3$	55	8/14/78-10/24/84	130	360	222	280	312	-	-

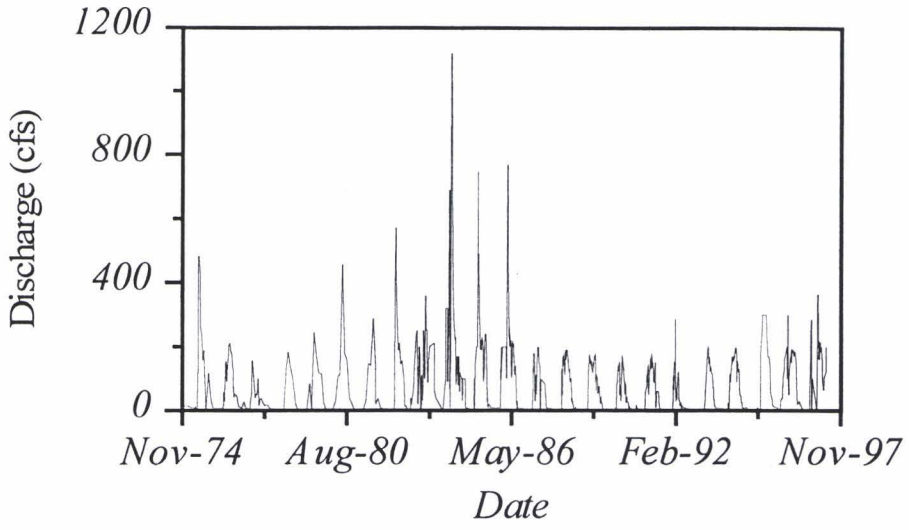


Figure 49. Scofield reservoir discharge to Price River.

Water Quality of Mine Discharge

Table 28 shows the summary water quality data at the mine discharge station 173449. The data indicate the presence of TDS and iron as the COC with maximum values of 718 and 3.2 mg/L, respectively. These values are higher than the background values given in Table 3. For example, TDS is more than twice as high and iron is more than one order of magnitude higher. Table A22 in Appendix A indicates iron increased the seasonal trend with poor probability. The time-series data shown in Figures 50a and 50b for iron and manganese clearly indicate that iron concentrations have been increasing during this period while manganese showed an inconclusive trend. The dissolved oxygen concentrations were not reported at this station, and heavy metal concentration data were almost non-existent. Based on the water quality data given here, it can be concluded that iron remains to be the only concern at this mine discharge station.

Water Quality of Mud Creek

The summary water quality data at the upstream stream station, 173475, are given in Table 29. The data indicate the presence of high TSS concentrations around 14,025 mg/L and TDS

of 779 mg/L during 1977 to 1995. In addition, iron and manganese concentrations were as high as 72.8 and 6.5 mg/L, respectively. These reported maximum concentrations are much higher than the background values reported in Table 3. Table A23 in Appendix A indicates that TSS has a reducing seasonal trend whereas TDS has an increasing seasonal trend. Figures 51a and 51b show the time-series distributions of TDS and iron at this station. The TDS data clearly show an overall increasing trend whereas iron shows an isolated peak value around 1984. The dissolved oxygen concentrations were relatively high indicating good aerobic conditions, and there were no concerns related to pH or heavy metals.

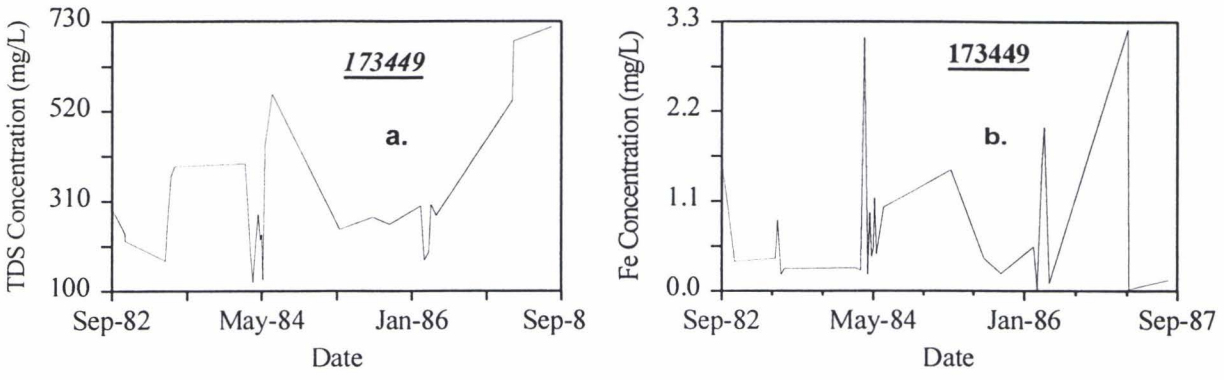


Figure 50. Time-series distributions of TDS and iron at Station 173449.

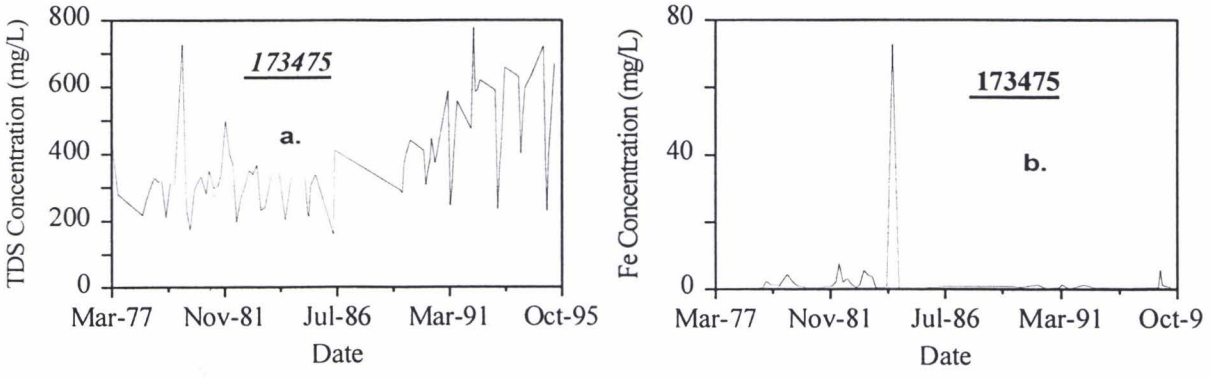


Figure 51. Time-series distributions of TDS and iron at Station 173475.

The water quality data at the next downstream location, 173474, are given in Table 30. The data indicate high concentrations of TSS, TDS, iron, manganese, and sulfate from 1977 to 1995. The maximum reported TSS, TDS, iron, manganese, and sulfate concentrations were 6460, 1202, 402, 2.1, and 370 mg/L, respectively. Also, these parameters violated the MCLs by 30 to 50 times in some cases indicating a consistent pattern of violations. Table A24 in Appendix A indicates increasing seasonal trends of TDS, iron, sulfate, and manganese with good probability. Figures 52a to 52c show the time-series distributions of TDS, manganese, and sulfate at this station. The data indicate that TDS was consistently high, manganese peaked several times between 1982 and 1985, and sulfate increased substantially after 1991. Fortunately, the dissolved oxygen concentration remained high, and no serious concerns related to pH or heavy metals were observed.

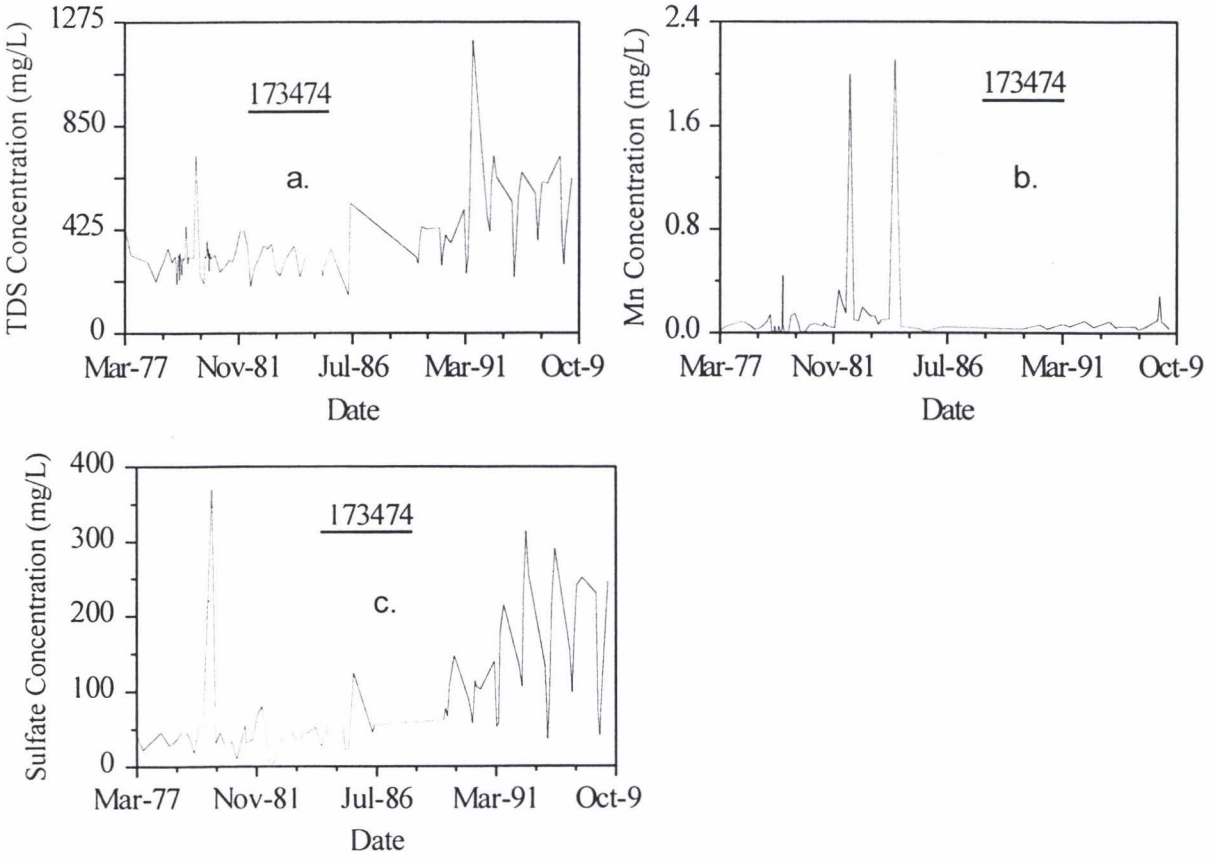


Figure 52. Time-series distributions of TDS, manganese, and sulfate at Station 173474.

The data from the USGS station, 09310700, are limited, as shown in Table 31; and, therefore, these data cannot be used in interpreting the long-term behavior.

The data from the two stream stations monitored by White Oak Mine indicate that the downstream locations of Mud Creek have no flow concerns. However, there are serious water quality concerns related to TDS, TSS, iron, sulfate, and manganese which cannot be explained by the available data. One strong possibility is the poor quality of water entering Mud Creek through Eccles Creek as discussed previously. However, the poor water quality of Eccles Creek alone cannot be held responsible for these dramatic increases of concentrations along Mud Creek. Due to the availability of limited data, it can be concluded that the water quality of other tributaries and base flow recharging Mud Creek may be partly responsible for these water quality concerns. Due to the poor quality of water present in Mud Creek, the water quality of Scofield Reservoir may be affected. Since the flow velocities in the reservoir are small, dilution and other mixing mechanisms from water coming from other tributaries may not be able to reduce the water quality concerns. In order to understand the net impact of Mud Creek and other tributaries, water quality sampling within the reservoir should be performed.

Ground Water Quality

The only available ground water monitoring station, 173451, is located upstream of Up Canyon in the eastern bank of Mud Creek. The summary water quality data at this station are given in Table 32. The data did not include heavy metals or dissolved oxygen concentrations. The remaining data are also limited, especially related to identified COC. These COC are TDS, iron, sulfate, and manganese between the short time period of 1993 and 1996. The maximum reported TDS, iron, sulfate, and manganese concentrations were 830, 2.5, 305, and 0.1 mg/L, respectively. Compared to the background values reported in Table 3, TDS, iron, and sulfate can be considered to be of some concern. The extreme sulfate concentrations are comparable to the water quality of Mud Creek reported at Station 173474. The trend data are not reported here as they were poor. Figures 53a through 53c show the concentrations of TDS, iron, and sulfate during 1993 to 1996. The data show that

Table 32. Summary water quality data at Groundwater Well 173451 in the Price River Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
pH	**8**	**09/01/93-10/28/96**	**6.5**	**7.9**	**7.4**	**6.9**	**-**	**6.5-8.5**	**0**
TSS	1	06/21/95	65	65	65	-	-	-	-
TDS	**8**	**09/01/93-10/28/96**	**500**	**830**	**700**	**607.5**	**-**	**500**	**7**
S. Cond. (µmhos/cm)	8	09/01/93-10/28/96	723	1116	932	905.8	-	-	-
Iron	**7**	**09/01/93-10/28/96**	**0.1**	**2.5**	**1.3**	**0.828**	**-**	**0.3**	**4**
Sulfate	**8**	**09/01/93-10/28/96**	**58**	**305**	**207.5**	**147.7**	**-**	**250**	**1**
Nitrate	1	09/01/93	0.01	0.01	-	0.01	-	10	0
Orthophosphate	1	06/21/95	0.1	0.1	0.1	-	-	-	-
Manganese	**7**	**09/01/93-10/28/96**	**0.048**	**0.1**	**0.1**	**0.0896**	**-**	**0.05**	**6**
Magnesium	3	09/01/93-06/21/95	28	31.2	28	31	-	-	-
Calcium	3	09/01/93-06/21/95	106	168	143	137	-	-	-
Bicarbonate as HCO_3^-	8	09/01/93-10/28/96	368	465	386.5	440.2	-	-	-
Total Alkalinity as $CaCO_3$	5	06/21/95-10/28/96	345	380	345	369	-	-	-
Total Hardness as $CaCO_3$	8	09/01/93-10/28/96	393	653	561.5	498	-	-	-

TDS concentrations were consistently high, iron concentrations peaked after 1995, and sulfate behaved similar to iron.

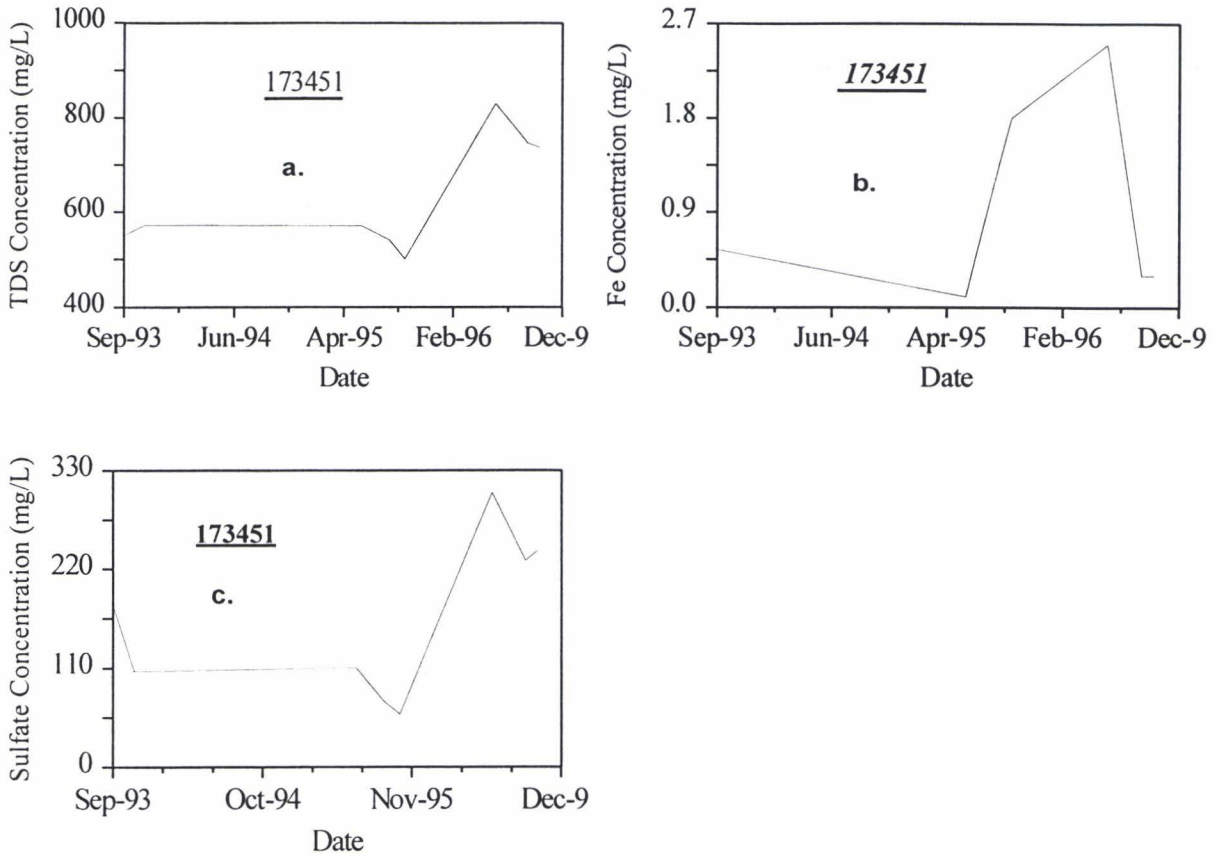


Figure 53. Time-series distributions of TDS, iron, and sulfate at Station 173451.

The data from this ground water monitoring station indicate that the quality of water is poorer than at previously analyzed ground water locations. In fact, the quality of water is as poor as downstream locations of Mud Creek, discussed earlier. Since the water table is located at an elevation close to the coal mining operations, it is possible that this location may be affected by coal mining. However, there is no definite proof to validate this possibility without the data from a tracer study, and the natural geochemical reactions occurring in the subsurface may also be partly responsible for the poor ground water quality.

4.2.8 Burnout Creek

Burnout Creek is located in the Huntington Watershed as shown in Figure 14. However, the flow and quality of Burnout Creek and a spring located near the creek were analyzed in this work as these stations are located within the permitted land of Skyline Mine.

The summary water flow and quality data at stream station 173419 are given in Table 33. It should be noted that this station is located close to the intersection of Burnout Creek with Electric Lake. The data in Table 33 show that the flow varied from 0.09 to 10.7 cfs between 1981 and 1996. The highest flow was in Season 1 with a mean of 2.8 cfs, and the flows during the other seasons were almost one order of magnitude less. The results in Table A25 in Appendix A indicate a decreasing seasonal trend of 0.022 cfs per year with good probability. The time-series distribution of flow is given in Figure 54a where it is seen that high flows occurred prior to 1984 and again after 1992.

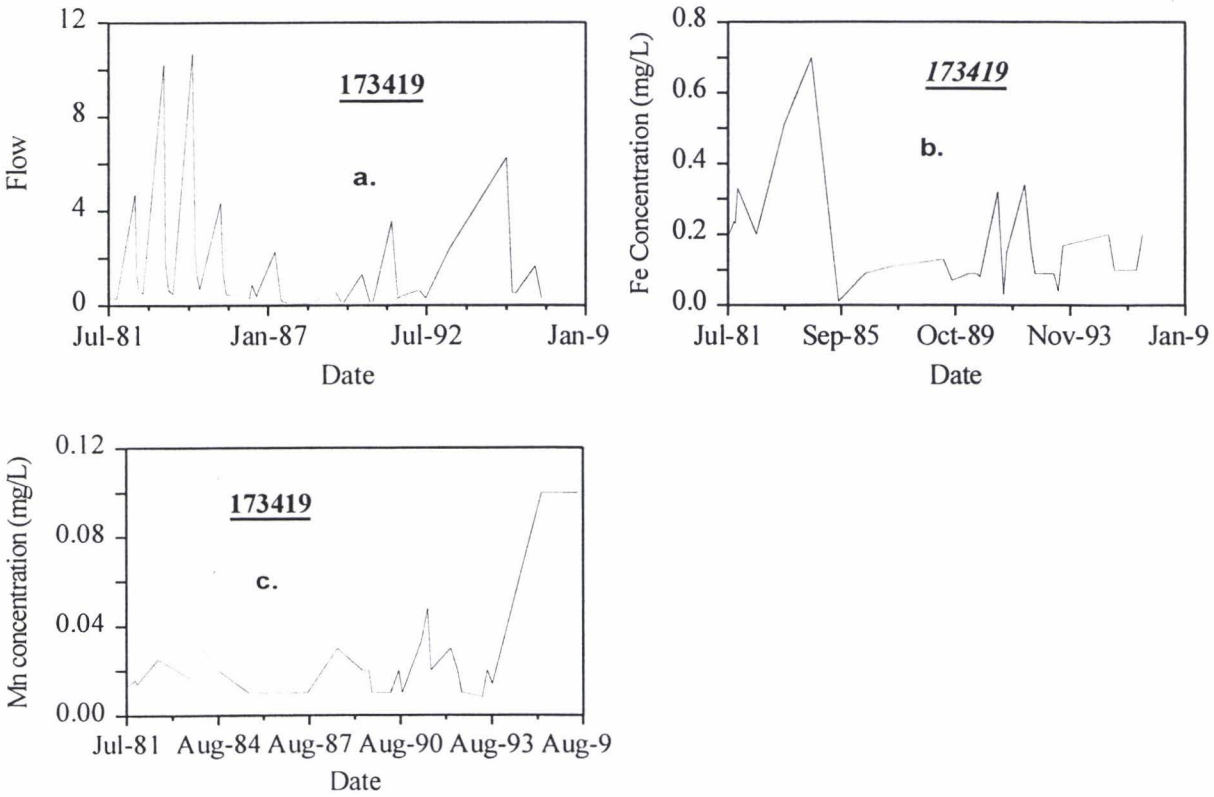


Figure 54. Time-series distributions of flow, iron, and sulfate at Station 173419.

Table 33. Summary water quality data at Stream Station 173419 of Burnout Creek in the Huntington Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	51	07/30/81-09/11/96	0.09	10.7	2.8	0.4085	0.2799	-	-
pH	**51**	**06/28/82-09/11/96**	**6.6**	**8.6**	**7.9**	**7.9**	**-**	**6.5-8.5**	**1**
TSS	31	07/31/81-09/11/96	1	20	9.8	6.7	3	-	-
TDS	31	07/30/81-09/11/96	1.8	300	190.4	204.5	249	500	0
Dissolved Oxygen	17	07/30/81-09/11/96	5	13	7.6	7.6	13	-	-
S. Cond. (µmhos/cm)	50	06/28/82-09/11/96	45	542	362.2	371	-	-	-
Chromium	1	11/10/81	0.001	0.001	-	-	0.001	0.05	0
Cadmium	1	11/10/81	0.001	0.001	-	-	0.001	0.01	0
Mercury	1	11/10/81	0.0002	0.0002	-	-	0.0002	0.002	0
Arsenic	1	11/10/81	0.001	0.001	-	-	0.001	0.05	0
Lead	**15**	**11/10/81-09/11/96**	**0.001**	**0.1**	**-**	**0.0162**	**0.001**	**0.05**	**2**
Zinc	8	11/10/81-08/18/88	0.002	0.036	-	0.0131	0.021	5	0
Iron	**31**	**07/30/81-09/11/96**	**0.01**	**0.7**	**0.1825**	**0.1592**	**0.28**	**0.3**	**5**
Sulfate	31	07/30/81-09/11/96	3	79	11.2	9.6	62.5	250	0
Nitrate	23	11/10/81-10/27/93	0.02	1.2	0.386	0.6518	0.4	10	0
Orthophosphate	5	06/22/95-09/11/96	0.01	0.03	0.02	0.0167	-	-	-
Manganese	**31**	**07/30/81-09/11/96**	**0.008**	**0.1**	**0.0393**	**0.03**	**0.015**	**0.05**	**5**
Magnesium	22	0730781-09/11/96	8.2	15.1	10.3	11.8	10.8	-	-
Calcium	22	07/30/81-09/11/96	49	70.5	56.8	61.4	67	-	-
Bicarbonate as HCO_3^-	31	07/30/81-09/11/96	160	345.3	196.5	233	215.4	-	-
Total Alkalinity as $CaCO_3$	18	10/22/81-09/11/96	140	283	140	193.7	202.6	-	-
Total Hardness as $CaCO_3$	8	06/09/92-06/24/96	160	233	182	213.8	-	-	-

The summary water quality data at this stream station are also shown in Table 33. The data show lead, iron, and manganese are the COC. However, these concentrations are comparable to the background values given in Table 3 and exceeded the MCLs by 2 to 5 times only from 1981 to 1996. Figures 54b and 54c show the time-series distributions of iron and manganese at this station. Table A25 in Appendix A shows small increasing trends of lead and manganese at this station. Due to the presence of concentrations comparable to background values, the impact of these chemicals on surface water quality may be minimal. Also, the heavy metals data from this site are limited, and dissolved oxygen concentrations remained high.

The summary water flow data at Spring 173440 are shown in Table 34. This spring is located at 9,440 feet elevation in the Skyline Mine permitted area. The data show that flow varied between 0 and 0.0186 from 1981 to 1996. The trend analysis showed that flow has no seasonal trend with good probability. Figure 55 shows the time-series distribution of flow where flow was high until the summer of 1986 and thereafter, the flow remained relatively small.

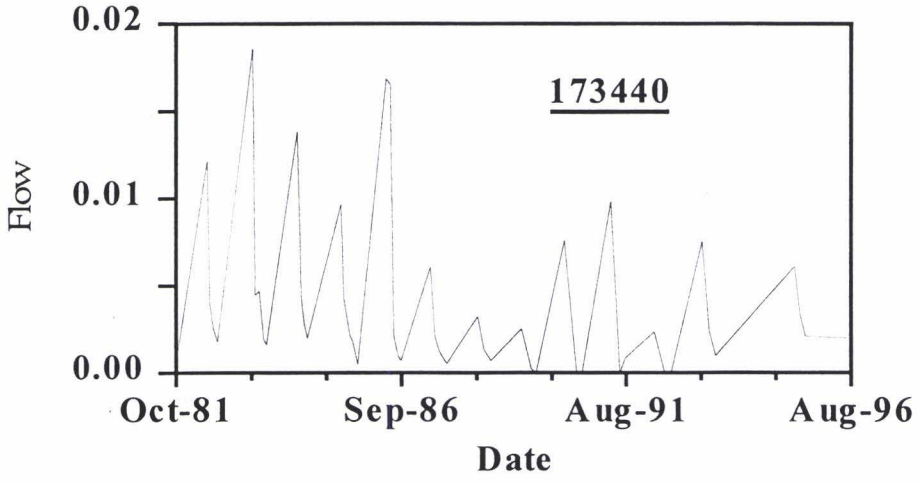


Figure 55. Time-series distribution of flow at Station 173440.

Table 34. Summary water quality data at Spring 173440 in the Huntington Watershed obtained from the Skyline Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	51	10/22/81-09/12/96	0	0.0186	0.008	0.0013	-	-	-
pH	**43**	**06/29/82-09/12/96**	**6**	**8**	**6.7**	**6.8**	**-**	**6.5-8.5**	**0**
TSS	32	06/29/82-09/12/96	1	11	2.8	2.5	-	-	-
TDS	31	06/29/82-09/12/96	115	275	180.8	234.2	-	500	0
Dissolved Oxygen	11	08/24/83-09/12/96	1.9	6.9	6.9	4.8	-	-	-
S. Cond. (µmhos/cm)	43	06/29/8209/12/96	194	483	323.2	417.2	-	-	-
Lead	**11**	**08/18/82-09/12/96**	**0.001**	**0.1**	**-**	**0.0195**	**-**	**0.05**	**2**
Zinc	7	08/18/8208/17/88	0.001	0.031	-	0.008	-	5	0
Iron	31	06/29/82-09/12/96	0.01	0.27	0.1175	0.0511	-	0.3	0
Sulfate	32	06/29/82-09/12/96	1	114	18	13	-	250	0
Nitrate	16	08/18/82-10/18/93	0.02	2.7	1.7	1.5	-	10	0
Orthophosphate	4	07/19/95-09/12/96	0.04	0.12	0.12	0.0533	-	-	-
Manganese	**31**	**06/29/82-09/12/96**	**0.001**	**0.1**	**0.0169**	**0.0241**	**-**	**0.05**	**4**
Magnesium	26	06/29/82-09/12/96	0.1	30.2	5.7	10	-	-	-
Calcium	26	06/29/82-09/12/96	32.8	102.8	50.9	70.9	-	-	-
Bicarbonate as HCO_3^-	32	06/29/82-09/12/96	96	295	165.3	253.1	-	-	-
Total Alkalinity as $CaCO_3$	11	08/18/82-09/12/96	192	237	-	206.5	-	-	-
Total Hardness as $CaCO_3$	4	06/09/92-10/18/93	163	248	182.5	243	-	-	-

Since this spring was selected to represent the background values, the water quality data will not be discussed or compared with other locations. The summary water quality data are given in Table 34.

4.3 Starpoint Mine

4.3.1 Background Concentrations

The Starpoint Mine is located southeast of the White Oak and Skyline Mines. Since the background concentrations of parameters of interest may be different to those of the other two mine areas, it was decided to establish the new background values from sources close to the Starpoint Mine. For this purpose, Spring 173330 was selected as it is located much further from the ongoing coal mining operations of the Starpoint Mine. Since commonly occurring parameters were similar to those found in the other two mines, TDS, TSS, sulfate, iron, and manganese were selected as potential chemicals of concern. In regards to TSS, there is a possibility that streams may exhibit higher background values than those represented by springs due to mechanisms such as bed erosion during peak flow times. Therefore, three stream stations, 173300, 173297, and 173295, from the Starpoint Mine data base were selected to represent the background value of TSS. The final set of established background concentrations is given in Table 35. It should be noted here that these background values may not necessarily represent the true background values as concentrations even under perfect natural conditions can change over time and space, especially in a large watershed such as the Price River. Therefore, these concentrations should be viewed and used as guidelines only.

Table 3 also shows the background values used in the analysis of the Huntington Watershed for comparison purposes. However, the background concentrations applicable to the Starpoint Mine will be used in this analysis.

Table 35. Range of background concentrations and MCLs of selected parameters for Starpoint Mine.

Parameter	Background Concentration (mg/L)	Background Concentration from Huntington Watershed (mg/L)	MCL (mg/L)
TSS	46-318	92	-
TDS	310	426	500
Iron	0.27	1.1	0.3
Sulfate	50	90	250
Manganese	0.03	0.06	0.05

4.3.2 Tie Fork Canyon Area

Figure 15 shows the Starpoint Mine permitted area where it is seen that Tie Fork Canyon is located in the Huntington Watershed. Tie Fork Canyon was formed as the result of the joining of Wild Cattle Hollow and Gentry Hollow slightly upstream of Huntington Creek. Tie Fork Canyon flows southwest and joins Huntington Creek upstream of the Bear Canyon intersection. Since Starpoint Mine is a focus area of this study, Tie Fork Canyon and the surrounding area were included in the analysis. The selected monitoring stations from this area include one stream station (173300), two springs (173339 and 173316), and three ground water wells (173345, 173344, and 173350).

Since the selected monitoring stations are scattered in the permitted land and do not follow a strict surface water network, the flow and quality data will be discussed simultaneously.

Wild Cattle Hollow

Wild Cattle Hollow is the western branch of Tie Fork Canyon and stream station 173300 is located slightly upstream of the intersection with Tie Fork Canyon. The summary water flow and quality data of this station are given in Table 36. The data show that the flow

Table 36. Summary water quality data at Stream Station 173300 of Wild Cattle Hollow in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	39	10/03/80-06/17/97	0	8.44	1.28	0.202	0.468	-	-
pH	**39**	**10/0380-06/17/97**	**6.8**	**9.9**	**8.3**	**8.1**	**7.8**	**6.5-8.5**	**8**
TSS	28	10/03/80-06/17/97	0.1	46	9.1	6.6	2	-	-
TDS	**30**	**10/03/80-06/17/97**	**208**	**540**	**274.1**	**275.5**	**294.5**	**500**	**1**
Dissolved Oxygen	6	08/20/88-09/14/89	7.4	9	8.7	8.1	-	-	-
S. Cond. (µmhos/cm)	40	10/03/80-06/17/97	214	980	466.9	460.6	363.8	-	-
Chromium	1	09/07/83	0.05	0.05	-	0.05	-	0.05	0
Cadmium	1	09/07/83	0.005	0.005	-	0.005	-	0.01	0
Mercury	1	09/07/83	0.2	0.2	-	0.2	-	0.002	1
Arsenic	1	09/07/83	0.001	0.001	-	0.001	-	0.05	0
Lead	1	09/07/83	0.05	0.05	-	0.05	-	0.05	0
Zinc	2	09/07/83-09/17/91	0.007	0.01	-	0.0085	-	5	0
Iron	**30**	**10/03/80-06/17/97**	**0.01**	**0.43**	**0.1373**	**0.099**	**0.115**	**0.3**	**3**
Sulfate	30	10/03/80-06/17/97	2	47	24	24.5	16.5	250	0
Nitrate	2	09/07/83-10/01/96	0.21	0.74	-	0.475	-	10	0
Manganese	**27**	**10/03/80-06/17/97**	**0.001**	**0.07**	**0.0155**	**0.0104**	**0.013**	**0.05**	**1**
Magnesium	14	10/30/80-06/22/93	23	31.7	27.1	27.9	26.8	-	-
Calcium	12	10/03/80-01/05/84	18.4	124	61.1	56.2	71.7	-	-
Bicarbonate as HCO_3^-	30	10/03/80-06/17/97	185.1	370.9	236.6	261	344	-	-
Total Alkalinity as $CaCO_3$	27	12/30/80-06/17/97	152.3	304	223	249.4	288	-	-
Total Hardness as $CaCO_3$	18	09/03/88-06/17/97	216	317	254.7	292.5	-	-	-

varied from 0 to 8.4 cfs during 1980 to 1997. The mean of Season 1 was 1.28 cfs, and the means of the other two seasons were close to one order of magnitude less. The time-series flow data are shown in Figure 56 which shows relatively small flows except in 1993 when the peak flow of 8.4 cfs occurred. The flows at all other times between 1980 and 1998 remained less than 3 cfs. The trend analysis produced poor results. The means of Seasons 2 and 3 show small flows around 0.2 to 0.4 cfs indicating values comparable to other streams.

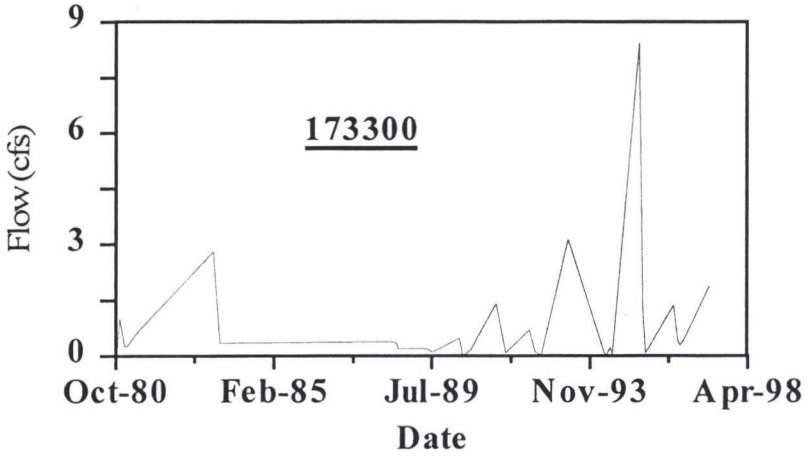


Figure 56. Time-series distribution of flow at Station 173300.

The water quality summary data given in Table 36 indicate that iron and manganese are the COC. However, these concerns can be disregarded as the peak values are comparable to the background values given in Table 35. In addition, the dissolved oxygen concentration was high in the stream indicating good aerobic conditions for fish habitat and no presence of organics. However, heavy metals data are limited and therefore, no conclusion can be made on impacts related to heavy metals.

Springs

The first spring, 173316, is located close to Wild Cattle Hollow at 9,440 feet of elevation in the Price River Formation. The summary water flow and quality data at this spring are given in Table 37. The flow varied from 0 to 0.096 cfs between 1992 and 1997, and the seasonal

Table 37. Summary water quality data at Spring 173316 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	16	05/20/92-06/18/97	0	0.096	0.018	0.0006	-	-	-
pH	**8**	**05/20/92-06/18/97**	**6.2**	**7.9**	**7.4**	**7**	**-**	**6.5-8.5**	**0**
TDS	8	05/20/92-06/18/97	284	310	290	303	-	500	0
S. Cond. (µmhos/cm)	8	05/20/92-06/18/97	485	916	624.7	519	-	-	-
Lead	3	06/17/9209/30/96	0.01	0.02	0.02	0.015	-	0.05	0
Zinc	2	06/17/92-09/21/92	0.01	0.05	0.05	0.01	-	5	0
Iron	**8**	**05/20/92-06/18/97**	**0.02**	**1.2**	**0.275**	**1**	**-**	**0.3**	**4**
Sulfate	8	05/20/92-06/18/97	4	99	37.3	30.5	-	250	0
Manganese	7	06/17/92-06/18/97	0.005	0.02	0.009	0.0135	-	0.05	0
Magnesium	2	06/17/92-09/21/92	20	20	20	20	-	-	-
Bicarbonate as HCO_3^-	8	05/20/92-06/18/97	188	284	258	257.6	-	-	-
Total Alkalinity as $CaCO_3$	8	05/20/92-06/18/97	188	284	260.7	265.5	-	-	-
Total Hardness as $CaCO_3$	8	05/20/92-06/18/97	268	314	287	295	-	-	-

trend analysis showed no trend with 32% probability. Also, it should be noted that the reported monitoring period is short, and there are only 16 data points compared to 30 or more from the other stations. The time-series flow data are shown in Figure 57a where it is seen that flow peaked at 0.096 cfs in late 1993 and thereafter, decreased. Since the number of data points is small and due to the sharp decrease of flow since 1993 as seen in Figure 57a, it seems that the available data are inadequate to make firm conclusions related to the long-term flow behavior at this spring. Therefore, it can be concluded that further close monitoring of this spring may be needed to determine the actual variability of flow with time.

The water quality data given in Table 37 indicate no serious concerns at this spring except slightly elevated iron concentrations. The peak iron concentration of 1.2 mg/L is relatively high compared to the background value of 0.27 mg/L. The time-series distribution of iron from 1992 to 1997 is given in Figure 57b. There were no reported oxygen concentrations or heavy metals at this spring. In general, it can be concluded that water quality data from this spring are limited, and no firm conclusion can be made regarding the behavior of water quality.

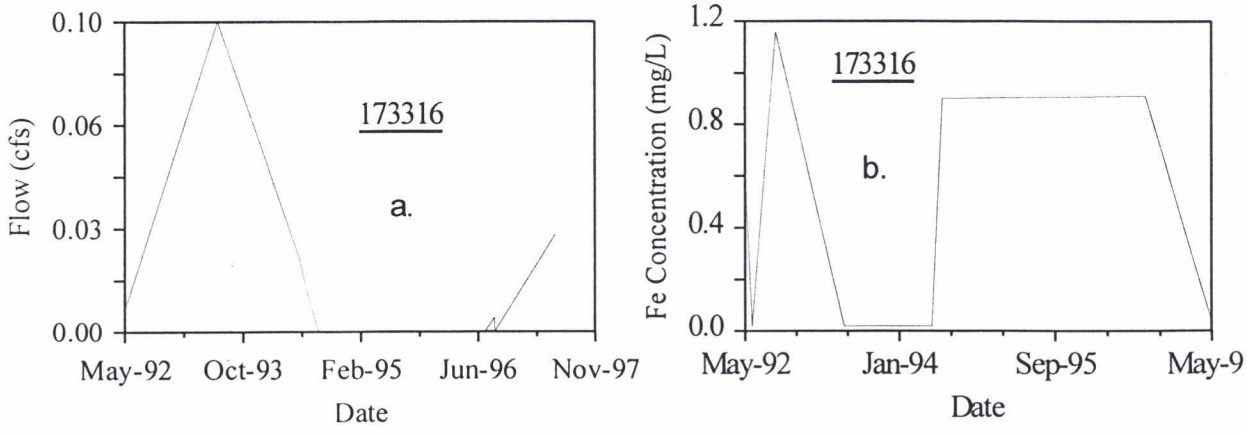


Figure 57. Time-series distributions of flow and iron at Station 173316.

Spring 173339 is located close to Gentry Hollow at 9,360 feet of elevation in the North Horn Formation. The summary water flow and quality data at this spring are given in Table 38. The flow at this spring was relatively high from 1988 to 1997 with a range of 0.01 to 0.19 cfs. The means of Season 1 and 2 were 0.054 and 0.031 cfs, respectively. The time-series distribution shown in Figure 58a indicates that the peak flow of 0.19 cfs occurred in 1995 with flows remaining around 0.04 cfs at other times. The results of the trend analysis produced an increasing seasonal trend of 0.003 cfs per year with good probability.

The summary water quality data given in Table 38 indicate that iron is the only chemical of concern with a peak value of 0.65 mg/L. This value is higher than the background value of 0.27 mg/L. However, compared to the potential variability of background values, the impact of iron can be disregarded. The time-series distribution of iron from 1988 to 1997 is shown in Figure 58b. Finally, there were no reported data on dissolved oxygen or heavy metals.

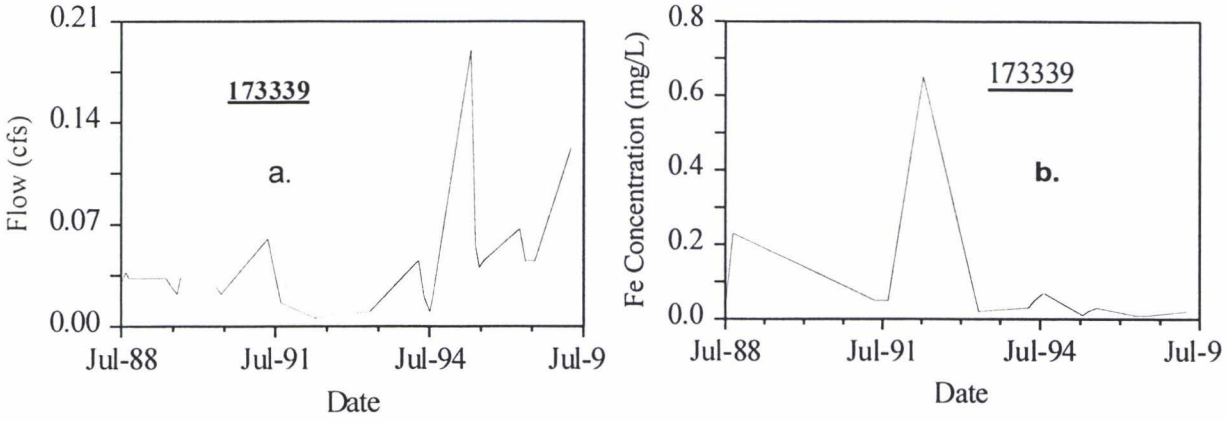


Figure 58. Time-series distributions of flow and iron at Station 173339.

Ground Water

There are three ground water monitoring locations selected from this area. The first well, 173345, is located upstream of Wild Cattle Hollow. The approximate location of the water table is between Blackhawk and Starpoint Sandstone Formations and around 8,000 feet of elevation. The summary water quality data at this station are given in Table 39 where it is

Table 38. Summary water quality data at Spring 173339 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	26	07/16/88-06/17/97	0.01	0.19	0.054	0.0314	-	-	-
pH	**26**	**07/16/88-06/17/97**	**6.2**	**8.2**	**7.3**	**7.6**	**-**	**6.5-8.5**	**0**
TDS	16	07/16/88-06/17/97	232	314	263.6	266	-	500	0
S. Cond. (µmhos/cm)	26	07/16/88-06/17/97	290	580	466.5	437	-	-	-
Lead	4	07/18/88-09/30/96	0.02	0.02	0.02	0.02	-	0.05	0
Zinc	3	07/16/88-09/17/91	0.01	0.01	0.01	0.01	-	5	0
Iron	**16**	**07/16/88-06/17/97**	**0.01**	**0.65**	**0.0809**	**0.078**	**-**	**0.3**	**1**
Sulfate	16	07/16/88-06/17/97	2	45	18.8	13.6	-	250	0
Manganese	15	07/16/88-06/17/97	0.005	0.01	0.0075	0.008	-	0.05	0
Magnesium	4	07/16/88-06/22/93	27	29	27.5	28	-	-	-
Bicarbonate as HCO_3^-	16	07/16/88-06/17/97	212	268	245.4	249.6	-	-	-
Total Alkalinity as $CaCO_3$	16	07/16/88-06/17/97	232	268	248.3	249.6	-	-	-
Total Hardness as $CaCO_3$	16	07/19/88-06/17/97	232	296	264.5	271.4	-	-	-

Table 39. Summary water quality data at Groundwater Well 173345 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
pH	**12**	**11/03/92-12/17/96**	**6.1**	**7.5**	**7.1**	**7.4**	**6.7**	**6.5-8.5**	**0**
TDS	14	11/03/92-12/17/96	360	450	401.2	395	386.6	500	0
S. Cond. (µmhos/cm)	12	11/03/92-12/17/96	620	7450	666.8	647.5	2051.4	-	-
Lead	6	11/03/92-12/17/96	0.02	0.04	0.02	-	0.025	0.05	0
Zinc	3	11/03/92-04/30/93	0.01	0.01	0.01	-	0.01	5	0
Iron	**14**	**11/03/92-12/17/96**	**0.25**	**5.8**	**2.6**	**0.475**	**0.6286**	**0.3**	**13**
Sulfate	14	11/03/92-12/17/96	40	84	63	50	60.3	250	0
Manganese	**14**	**11/03/92-12/17/96**	**0.019**	**0.262**	**0.1124**	**0.044**	**0.077**	**0.05**	**10**
Magnesium	2	11/03/92-04/30/93	31	38	38	-	31	-	-
Bicarbonate as HCO_3^-	14	11/03/92-12/17/96	266	344	321.8	320.5	320.1	-	-
Total Alkalinity as $CaCO_3$	14	11/03/92-12/17/96	274	344	327.4	320.5	321.3	-	-
Total Hardness as $CaCO_3$	14	11/03/92-12/17/96	326	422	381.8	369	367.7	-	-

seen that iron and manganese are the COC. The peak iron and manganese concentrations were 5.8 and 0.262 mg/L, respectively, and the time-series distributions are given in Figures 59a and 59b. These concentrations are about one order of magnitude higher than the background values reported in Table 35. The time-series distribution of manganese is shown in Figure 59b where it is seen that there is a sharp rise in concentration after 1995. There were no reported data on dissolved oxygen or heavy metals. Therefore, it can be concluded that this ground water location shows some concerns with respect to iron and manganese, but no rigorous action may be needed.

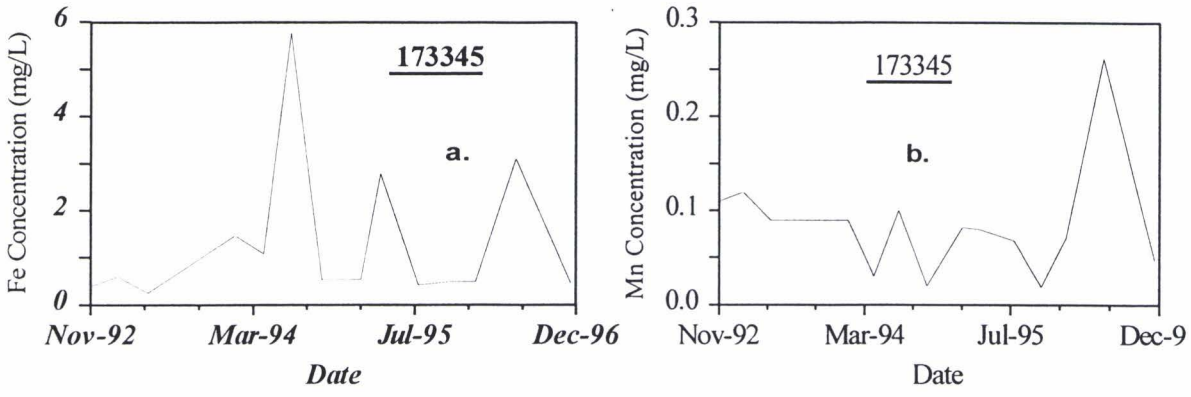


Figure 59. Time-series distributions of flow and manganese at Station 173345.

The next ground water monitoring well, 173344, is located east of the previous well, 173345. The water quality data at this station are given in Table 40 where it is seen that iron and manganese are the COC from 1992 to 1997. The manganese concentrations are relatively high compared to the background value given in Table 35, but comparable to the peak value exhibited by the previous ground water well. However, the iron concentration is high, around 28.7 mg/L, and almost two orders of magnitude higher than the background value. The time-series distributions of iron and manganese at this station are shown in Figures 60a and 60b, respectively. The results show that iron had a peak of 28.7 mg/L once in 1994 and remained less than 10 mg/L at other times. The manganese concentrations were relatively uniform until 1996 and thereafter, it showed an increasing trend. The trend

Table 40. Summary water quality data at Groundwater Well 173344 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
pH	**12**	**11/03/92-03/19/97**	**6.1**	**7.8**	**7.2**	**7.2**	**6.9**	**6.5-8.5**	**0**
TDS	15	11/03/92-03/19/97	360	450	420.8	415	406.8	500	0
S. Cond. (μmhos/cm)	13	01/27/93-03/19/97	467	780	693	617.5	721.5	-	-
Lead	6	11/03/92-12/17/96	0.01	0.05	0.035	-	0.0225	0.05	0
Zinc	3	11/03/92-04/30/93	0.03	0.08	0.06	-	0.055	5	0
Iron	**15**	**11/03/92-03/19/97**	**0.16**	**28.7**	**8.5**	**9.4**	**2.9**	**0.3**	**13**
Sulfate	15	11/03/92-03/19/97	60	113	85.4	73	78.4	250	0
Manganese	**15**	**11/03/92-03/19/97**	**0.106**	**0.504**	**0.213**	**0.225**	**0.2454**	**0.05**	**15**
Magnesium	3	11/03/92-04/30/93	34	44	44	-	38	-	-
Bicarbonate as HCO_3^-	15	11/03/92-03/19/97	258	350	308.2	329.5	324.8	-	-
Total Alkalinity as $CaCO_3$	15	11/03/92-03/19/97	266	350	308.2	329.5	325.8	-	-
Total Hardness as $CaCO_3$	15	11/03/92-03/19/97	331	434	384.2	394	402.4	-	-

analysis data produced poor results, possibly due to the limited data. Also, there were no reported data on dissolved oxygen or heavy metals.

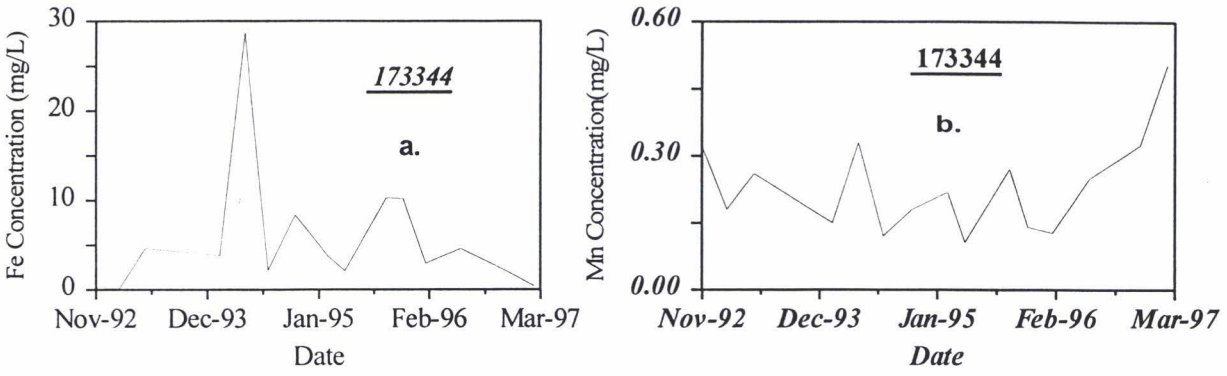


Figure 60. Time-series distributions of flow and manganese at Station 173344.

The last ground water monitoring well, 173350, is located close to stream station 173300, at the fork between Wild Cattle Hollow and Gentry Hollow. The summary water quality data at this station are given in Table 41. It should be noted that data at this station are limited, and there were no reported data on dissolved oxygen and heavy metals. The only chemical of concern is iron with a maximum concentration of 0.98 mg/L which is comparable to the background value given in Table 35. The time-series distribution of iron from 1988 to 1997 is shown in Figure 61 where it shows that the peak concentration occurred in 1988. Thereafter, the iron concentration remained at less than 0.5 mg/L for most of the time. The trend analysis indicated that iron was decreasing at a seasonal rate of 0.002 mg/L per year with 91% probability.

In general, it can be concluded that iron and manganese are the only parameters of concern in ground water quality. However, these peak concentrations are not as high as the values present in Eccles Creek or Whiskey Canyon discussed in the analysis of the White Oak and Skyline Mines. Yet, further monitoring of these locations may be needed to understand the actual long-term behavior of these constituents. There were no reported data on dissolved oxygen or heavy metals to determine the impacts of these parameters on water quality.

Table 41. Summary water quality data at Groundwater Well 173350 in the Huntington Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
pH	**41**	**07/09/88-06/17/97**	**6**	**8.3**	**7.2**	**7.4**	**6.7**	**6.5-8.5**	**0**
TSS	1	09/21/92	4	4	-	4	-	-	-
TDS	38	07/09/88-06/17/97	292	400	326.9	320	316.6	500	0
S. Cond. (μmhos/cm)	41	07/09/88-06/17/97	420	699	574.7	546.2	612.5	-	-
Lead	5	09/17/91-10/01/96	0.02	0.02	-	0.02	0.02	0.05	0
Zinc	3	09/17/91-02/28/93	0.01	0.02	-	0.02	0.01	5	0
Iron	**38**	**07/09/88-06/17/97**	**0.01**	**0.98**	**0.0835**	**0.14**	**0.0229**	**0.3**	**3**
Sulfate	38	07/09/88-06/17/97	19	76	35	40	40.1	250	0
Manganese	32	07/09/88-06/17/97	0.005	0.03	0.0093	0.0114	0.0098	0.05	0
Magnesium	5	09/17/91-06/22/93	27	31	29	30	29	-	-
Bicarbonate as HCO_3^-	38	07/09/88-06/17/97	226	327	287.2	279.9	280.9	-	-
Total Alkalinity as $CaCO_3$	38	07/09/88-06/17/97	182	327	283.6	283.9	284.9	-	-
Total Hardness as $CaCO_3$	38	07/09/88-06/17/97	250	356	320.8	326.5	323	-	-

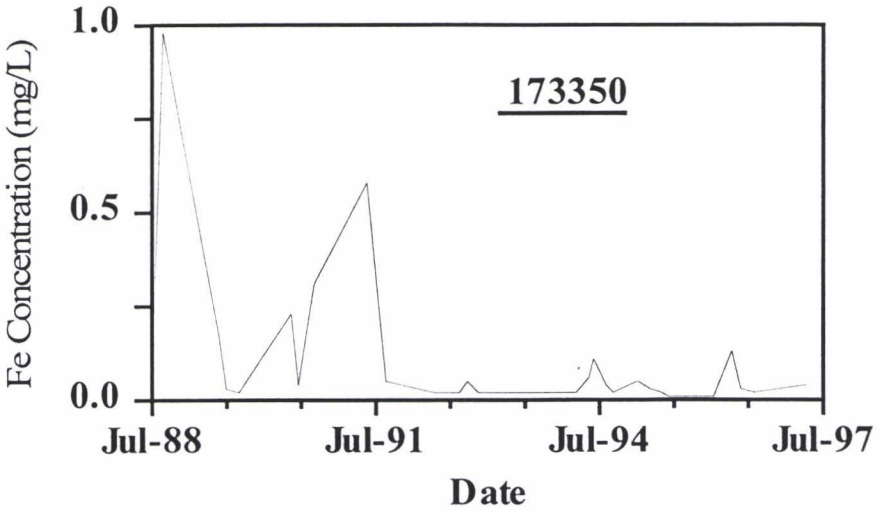


Figure 61. Time-series distribution of iron at Station 173350

4.3.3 Right Fork Miller Creek Area

The next area of focus within the Starpoint Mine permitted land is the Right Fork Miller Creek area and is shown in Figure 15. Right Fork Miller Creek flows southeast towards Hiawatha and has a major tributary from the northwest. The selected monitoring stations from this area include two stream stations (173297 and 173295), four mine interceptions from the Starpoint Mine (173352, 173575, 173353, and 173354), and four springs (173330, 173326, 173318, and 173320).

Mine Interceptions

The first mine interception station analyzed was 173575 located upstream of the Right Fork Miller Creek area and monitored by the Starpoint Mine. The summary water flow and quality data are given in Table 42. The data indicate that flow varied from 0 to 0.03 cfs between 1988 and 1997 with only 15 data points. The highest flow occurred in Season 1 followed by Seasons 3 and 2. The time-series flow data are shown in Figure 62a where it is

Table 42. Summary water quality data at Mine Interception Station 173575 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	15	07/27/88-06/12/97	0	0.03	0.006	0.0011	0.0022	-	-
pH	**8**	**07/27/88-06/12/97**	**7.3**	**8.2**	**7.7**	**7.5**	**7.4**	**6.5-8.5**	**0**
TDS	**8**	**07/27/88-06/12/97**	**772**	**1640**	**1092**	**1360**	**1366.7**	**500**	**8**
S. Cond. (µmhos/cm)	8	07/27/88-06/12/97	700	2100	1035	1565	1696.7	-	-
Lead	1	12/17/96	0.04	0.04	-	-	0.04	0.05	0
Iron	**7**	**07/27/88-06/12/97**	**0.03**	**1.7**	**0.6167**	**1.7**	**0.1033**	**0.3**	**3**
Sulfate	**8**	**07/27/88-06/12/97**	**372**	**990**	**559.5**	**750**	**783.3**	**250**	**8**
Manganese	**7**	**07/27/88-06/12/97**	**0.007**	**0.182**	**0.0287**	**0.182**	**0.01**	**0.05**	**2**
Bicarbonate as HCO_3^-	8	07/27/88-06/12/97	192	342	268.8	309	283	-	-
Total Alkalinity as $CaCO_3$	8	07/27/88-06/12/97	192	342	268.8	309	283	-	-
Total Hardness as $CaCO_3$	8	07/27/88-06/12/97	617	1230	877.8	1150	1090	-	-

seen that flow was present in 1988 and after 1995. At other times, either the flow was negligible or not present at all. The trend analysis indicated that flow has an increasing seasonal trend of 0.001 cfs per year with 89% probability.

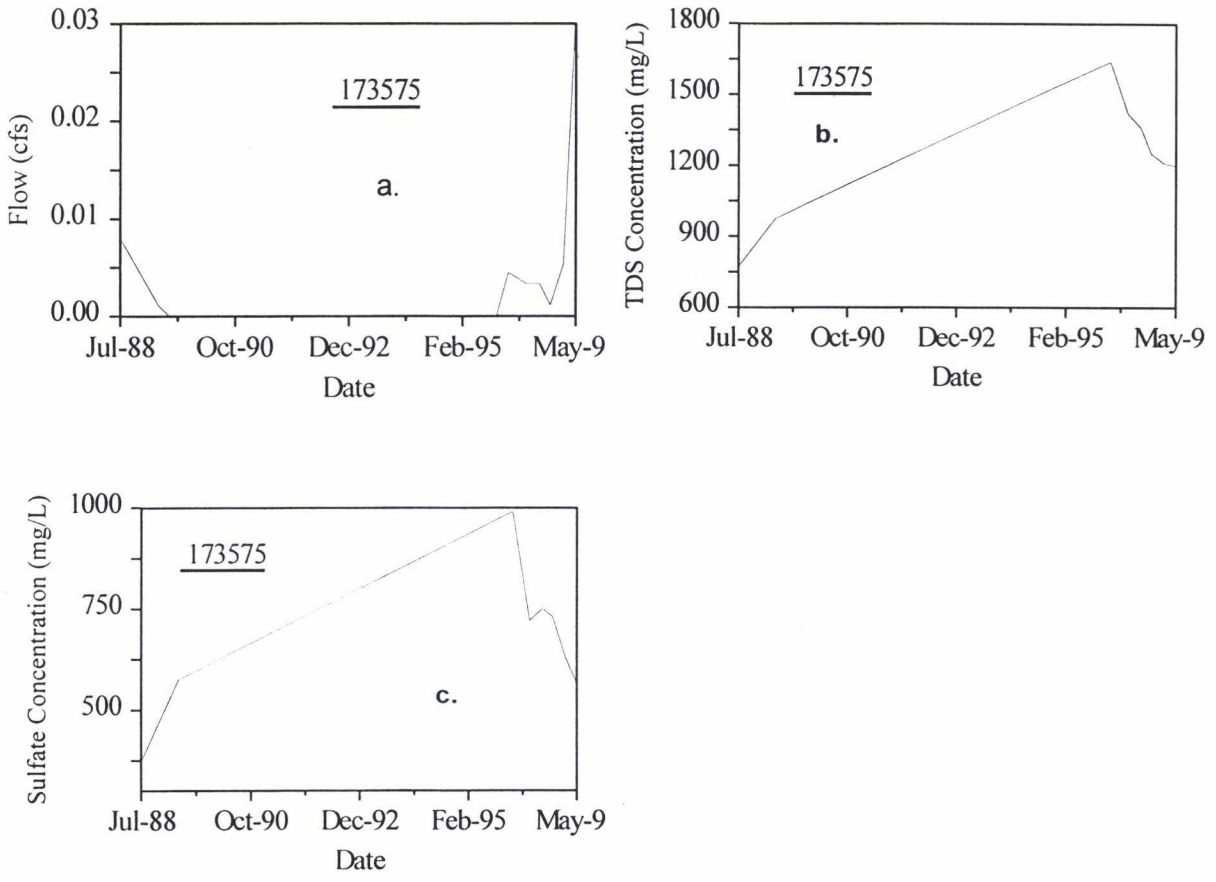


Figure 62. Time-series distributions of flow, TDS, and sulfate at Station 173575.

The water quality data indicate that TDS, iron, sulfate, and manganese are the COC. However, compared to the background values given in Table 35 and realizing the potential variability of chemical parameters in surface and subsurface water, it can be concluded that TDS and sulfate may be the only concerns at this station. Peak TDS and sulfate concentrations were 1640 and 990 mg/L, respectively. The time-series distributions of TDS and sulfate are shown in Figures 62b and 62c. Both parameters indicate increasing seasonal

trends from 1988 to early 1996 followed by a sharp decrease. However, the trend analysis produced trends with poor probability due to the limited number of data points. There were no reported data on dissolved oxygen or heavy metals.

The next mine interception station, 173353, is located slightly away from the previous mine interception station towards the east. The water flow and quality data are given in Table 43 indicating a maximum flow of 0.01 cfs from 1988 to 1995. The highest flow occurred in Season 2 followed by Seasons 3 and 1. The time-series flow distribution is shown in Figure 63a where it is seen that high flows were visible in 1988, and from 1992 to 1993. The trend analysis, given in Table A26 in Appendix A, indicates zero trend with poor probability. The water quality data suggest that TDS, TSS, iron, and sulfate are the concerns. The peak TDS and sulfate concentrations were 1118 and 634 mg/L respectively. Figures 63b through 63d show the concentrations of these COC except for TSS. The TDS concentration was consistently around 900 mg/L except for a short period in 1990. The iron concentration became excessive after 1991 with two high concentration spikes. Sulfate showed a consistently increasing concentration from 1988 to 1994. The results of the trend analysis, given in Table A26 in Appendix A, indicate that TDS, iron, and sulfate have increasing seasonal trends with good probability.

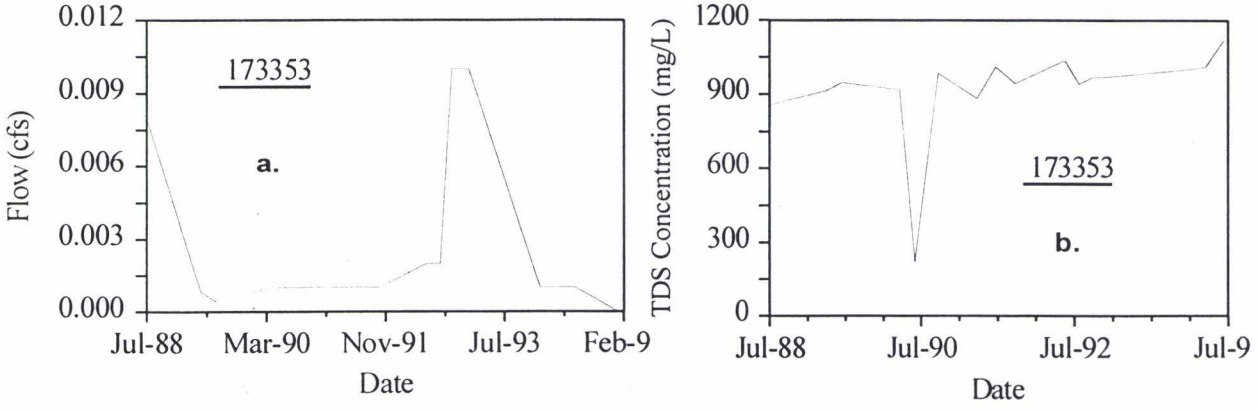


Table 43. Summary water quality data at Mine Interception Station 173353 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	16	07/27/88-02/27/95	0	0.01	0.0017	0.0043	0.0037	-	-
pH	**14**	**07/27/88-07/20/94**	**6.4**	**8.3**	**8**	**7.5**	**6.4**	**6.5-8.5**	**0**
TSS	**1**	**08/31/92**	**990**	**990**	**-**	**990**	**-**	**-**	**-**
TDS	**16**	**07/27/88-07/20/94**	**222**	**1118**	**891.2**	**958**	**985**	**500**	**15**
Dissolved Oxygen	0	-	-	-	-	-	-	-	-
S. Cond. (µmhos/cm)	14	07/27/88-07/20/94	780	1514	1160.7	1230	1514	-	-
Lead	1	10/28/91	0.02	0.02	-	0.02	-	0.05	0
Zinc	1	10/28/91	0.01	0.01	-	0.01	-	5	0
Iron	**16**	**07/27/88-07/20/94**	**0.02**	**5.2**	**1.1**	**1.8**	**1.2**	**0.3**	**9**
Sulfate	**16**	**07/27/88-07/20/94**	**463**	**634**	**524.7**	**521.8**	**582.5**	**250**	**16**
Manganese	12	07/27/88-07/20/94	0.01	0.05	0.0222	0.01	0.03	0.05	0
Magnesium	1	10/28/91	107	107	-	107	-	-	-
Bicarbonate as HCO_3^-	16	07/27/88-07/20/94	154	252	224.7	225	200	-	-
Total Alkalinity as $CaCO_3$	16	07/27/88-07/20/94	154	252	229.1	231	200	-	-
Total Hardness as $CaCO_3$	16	07/27/88-07/20/94	670	820	750.3	741	760	-	-

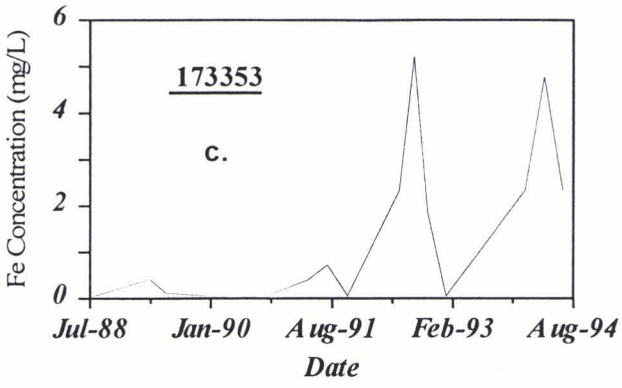


Figure 63. Time-series distributions of flow, TDS, and iron at Station 173353.

The next mine interception station, 173354, is located south of 173575. The summary water flow and quality data at this mine interception station are given in Table 44. The flow varied from 0.00002 to 0.008 cfs between 1992 and 1997. The seasonal means were same in all seasons with a value of 0.003 cfs indicating consistent flow during the entire monitoring period. It should be noted that data from this station are limited and available from 1992 to 1997 only. The time-series distribution, shown in Figure 64a, indicates that flow was increasing from 1992 to 1995 followed by a sharp decreasing trend. The results of the trend analysis, given in Table A27 in Appendix A, indicate that flow decreased at 0.001 cfs per year with perfect probability.

The water quality data suggest the presence of TDS, iron, sulfate, and manganese as the COC. However, compared to the background values given in Table 35, it can be concluded that serious concerns may arise due to TDS, iron, and sulfate only. Figures 64b through 64d show the time-series distributions of TDS, iron, and sulfate in the mine intercepted water. All three plots show increasing concentrations after the summer of 1995 whereas flow decreased during this period. In other words, flow at this station and concentrations of these three parameters behaved oppositely. The trend analysis results, given in Table A27 in Appendix A, show that all COC have high increasing seasonal trends with good probability;

Table 44. Summary water quality data at Mine Interception Station 173354 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	59	10/31/92-07/31/97	0.0002	0.008	0.003	0.003	0.003	-	-
pH	**16**	**10/31/92-06/12/97**	**6.3**	**9.1**	**7.6**	**7.4**	**7.5**	**6.5-8.5**	**1**
TSS	3	01/27/93-02/27/95	4	140	4	-	75	-	-
TDS	**18**	**10/32/92-06/12/97**	**358**	**870**	**548**	**475.5**	**480.8**	**500**	**8**
S. Cond. (µmhos/cm)	16	10/31/92-06/12/97	627	7720	787.8	732	1966.3	-	-
Lead	9	01/27/93-12/17/96	0.02	0.04	0.02	0.02	0.025	0.05	0
Zinc	4	10/31/92-04/30/93	0.01	0.01	0.01	0.01	0.01	5	0
Iron	**18**	**10/31/92-06/12/97**	**0.02**	**5.1**	**0.8333**	**0.275**	**1.3**	**0.3**	**7**
Sulfate	**18**	**10/31/92-06/12/97**	**76**	**330**	**166.2**	**124.5**	**141.4**	**250**	**1**
Manganese	**18**	**10/31/92-06/12/97**	**0.01**	**0.099**	**0.0478**	**0.0292**	**0.0512**	**0.05**	**5**
Magnesium	4	10/31/92-04/30/93	35	44	41	44	38	-	-
Bicarbonate as HCO_3^-	18	10/31/92-06/12/97	250	342	297.2	297.5	305.5	-	-
Total Alkalinity as $CaCO_3$	18	10/31/92-06/12/97	266	342	301.2	298.5	305.5	-	-
Total Hardness as $CaCO_3$	18	10/31/92-06/12/97	347	655	462.8	420.5	434.5	-	-

for example, TDS and sulfate had positive trends of 49.8 and 26.5 mg/L per year, respectively.

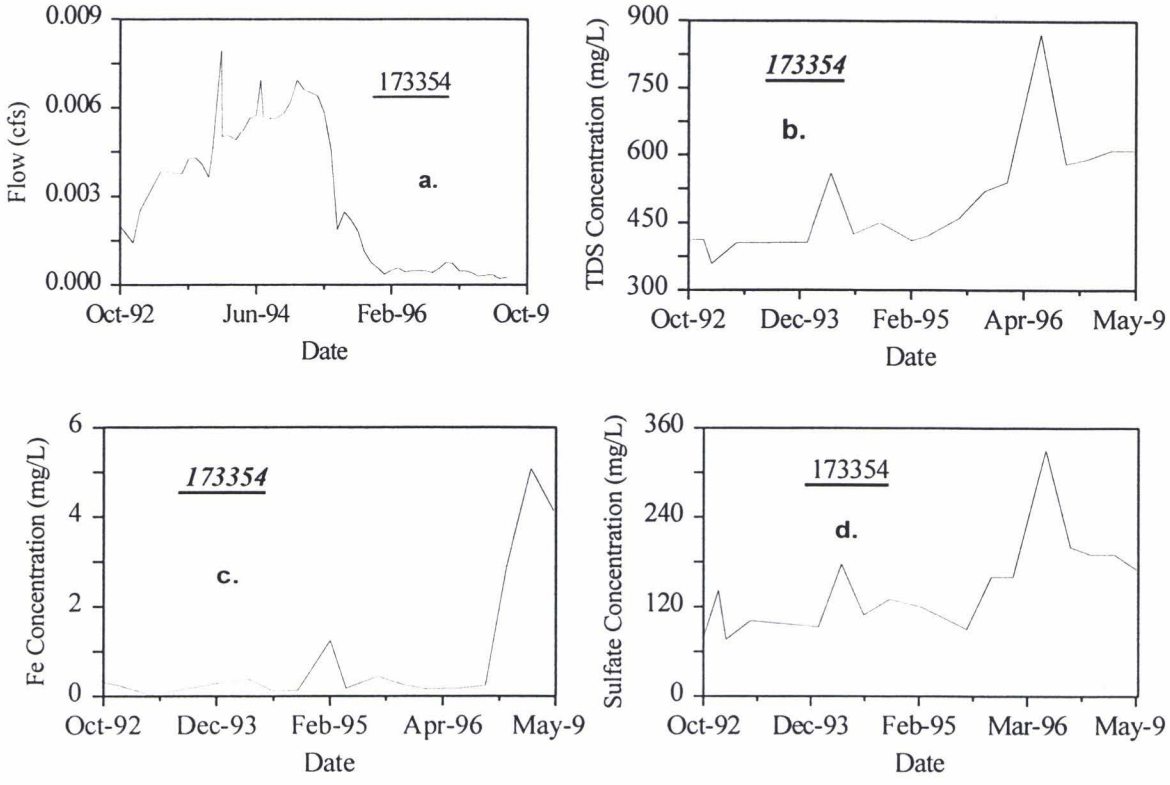


Figure 64. Time-series distributions of flow, TDS, iron, and sulfate at Station 173354.

The next mine interception station, 173352, is located further south from the previous stations and between Right Fork and North Fork. The summary flow and quality data at this station are shown in Table 45. The flow varied between 0.0002 and 0.4 cfs from 1988 to 1997. The flow was consistent during all seasons with values ranging from 0.05 to 0.09 cfs. The time-series distribution of mine intercepted flow is shown in Figure 65a where it is seen that flow was relatively uniform except in 1992 with a peak of 0.4 cfs. At all other times, the flow was around 0.05 cfs and comparable to the other mine interception stations except the previous station, 173354. The trend analysis produced a decreasing seasonal trend of 0.008 cfs per year with 90% probability.

Table 45. Summary water quality data at Mine Interception Station 173352 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	26	07/27/88-06/12/97	0.0002	0.3999	0.0626	0.0542	0.0915	-	-
pH	**25**	**07/27/88-06/12/97**	**6.1**	**8.2**	**7.5**	**7.3**	**7.2**	**6.5-8.5**	**0**
TSS	1	08/31/92	2	2	-	2	-	-	-
TDS	**28**	**07/27/88-06/12/97**	**1182**	**1410**	**1285.7**	**1302**	**1277.1**	**500**	**28**
S. Cond. (µmhos/cm)	25	07/27/88-06/12/97	1010	1920	1469.4	1502.3	1606.8	-	-
Lead	2	10/28/91-12/17/96	0.02	0.04	-	0.02	0.04	0.05	0
Zinc	1	10/28/91	0.01	0.01	-	0.01	-	5	0
Iron	**28**	**07/27/88-06/12/97**	**0.01**	**0.37**	**0.0471**	**0.0214**	**0.0771**	**0.3**	**2**
Sulfate	**28**	**07/27/88-06/12/97**	**587**	**800**	**707.6**	**770.6**	**729.4**	**250**	**28**
Manganese	23	07/27/88-06/12/97	0.005	0.02	0.0088	0.009	0.008	0.05	0
Magnesium	1	10/28/91	118	118	-	118	-	-	-
Bicarbonate as HCO_3^-	28	07/27/88-06/12/97	134	357	273.2	261.1	259.4	-	-
Total Alkalinity as $CaCO_3$	28	07/27/88-06/12/97	134	357	275.5	264.6	259.4	-	-
Total Hardness as $CaCO_3$	28	07/27/88-06/12/97	854	1120	984.6	968.4	973.4	-	-

The summary water quality data given in Table 45 indicate that TDS, iron, and sulfate are the COC with peak concentrations of 1410, 0.37, and 800 mg/L, respectively. Based on the background values given in Table 35, it can be concluded that TDS and sulfate are the only concerns at this station. The time-series distributions of TDS and sulfate are shown in Figures 65b and 65c, respectively. These plots indicate consistently high concentrations with slightly increasing trends. The trend analysis indicated that TDS has an increasing seasonal trend of 12.9 mg/L per year with good probability whereas the trend results for other parameters were poor.

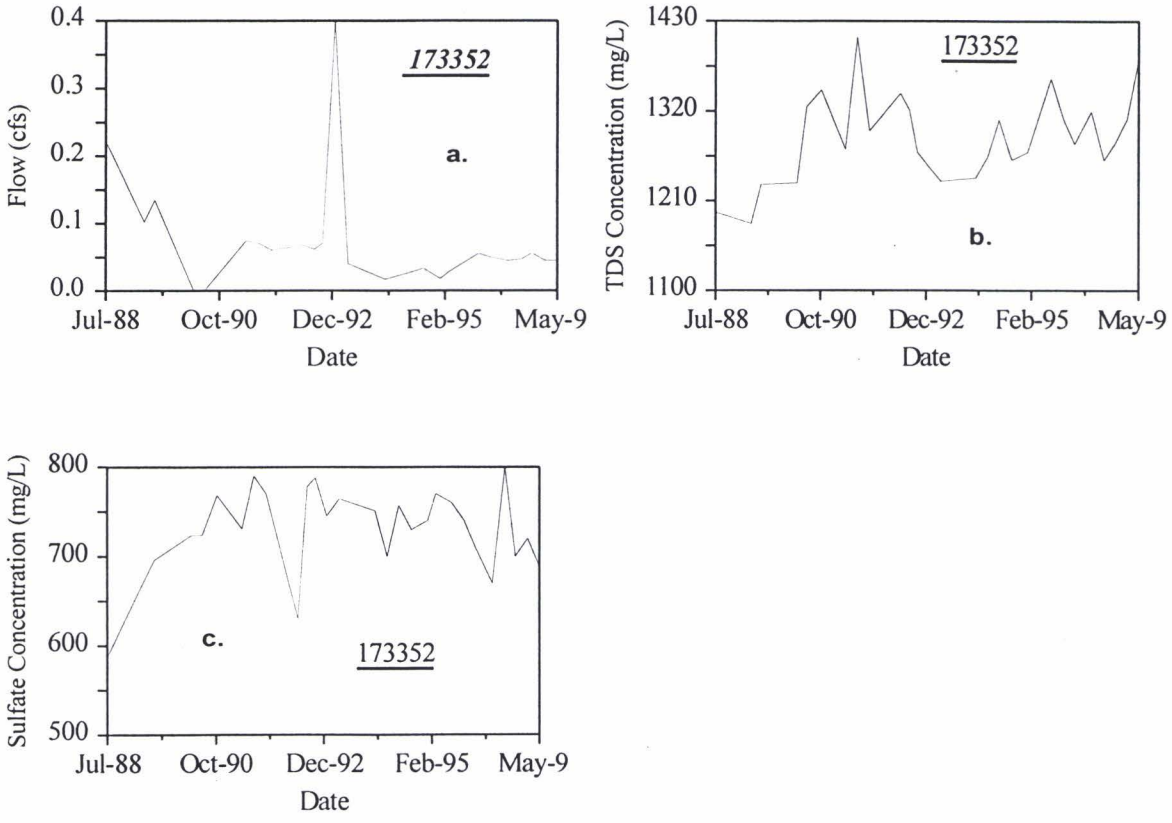


Figure 65. Time-series distributions of flow, TDS, and sulfate at Station 173352.

In general, the mine interception data indicate that the Starpoint Mine was intercepting water continuously since 1988. The flow remained almost the same between different seasons

indicating that mine intercepted water may be linked to a continuous flow network. The water quality was poor with respect to TDS, iron, sulfate, and manganese. However, compared to mine discharge and stream water quality observed in Eccles Creek, the water quality of these mine interceptions are better, yet needs careful monitoring and assessment. Unfortunately, the data from these mine interception stations are limited or sometimes not available, especially on dissolved oxygen and heavy metals.

Stream Stations

The two stream stations are located along the upstream tributary of Right Fork Miller Creek. The upstream station, 173297, is analyzed first. The summary water flow and quality data at this station are given in Table 46 where it is seen that flow varied from 0.001 to 2.2 cfs between 1988 and 1997. The mean of Season 1 was 0.27 cfs and that of Season 2 was 0.04 cfs. Data from Season 3 were inadequate to determine a mean value. The time-series distribution of flow given in Figure 66a shows two peaks in 1991 and 1995. Except for these peaks, the flow at this location remained relatively small. The trend analysis produced results with poor probability, mainly due to the presence of these isolated peaks. The water quality data suggest the presence of TDS, iron, sulfate, and manganese as the COC with peak values of 1,700, 3.3, 1,030, and 0.11 mg/L, respectively. Based on the background values given in Table 35, the most serious concerns may be due to TDS and sulfate and to a lesser degree on iron. The time-series data of TDS and sulfate are shown in Figures 66b and 66c, respectively. The data show that TDS was consistently high from 1989 to 1997 except in 1995 for a short period, and a similar behavior is observed with sulfate as well. The trend results were poor due to the presence of isolated low peaks in the time-series data.

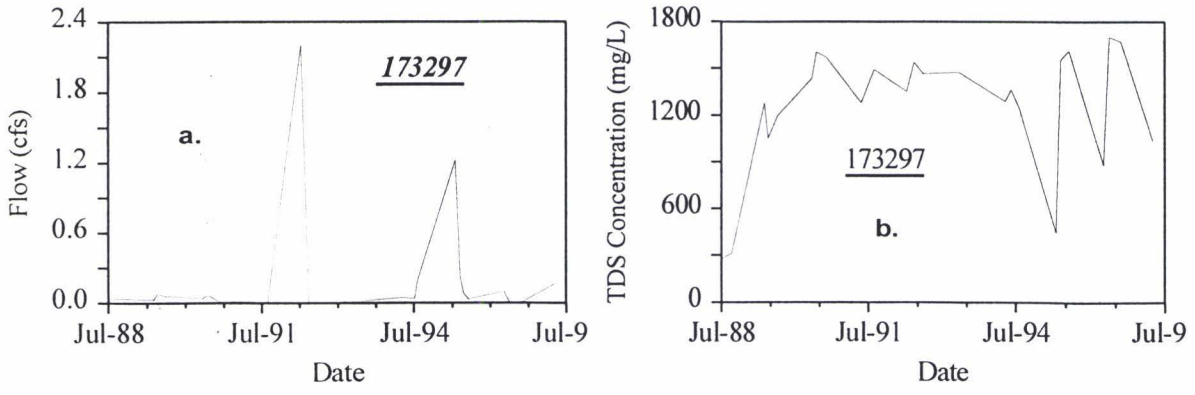


Table 46. Summary water quality data at Stream Station 173297 of North Fork of the Right Fork Miller Creek in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	30	07/15/88-06/18/97	0.001	2.2	0.2669	0.0409	-	-	-
pH	**31**	**07/05/88-06/18/97**	**6.9**	**9.6**	**8.3**	**8.5**	**-**	**6.5-8.5**	**8**
TSS	16	07/04/90-06/18/97	2	318	32.2	16	-	-	-
TDS	**24**	**07/15/88-06/18/97**	**276**	**1700**	**1221.8**	**1319.8**	**-**	**500**	**21**
Dissolved Oxygen	6	08/13/88-09/15/89	7.2	9.2	8.3	8	-	-	-
S. Cond. (µmhos/cm)	31	07/05/88-06/18/97	1	2320	1333.8	1329.1	-	-	-
Zinc	7	07/15/88-09/17/91	0.01	0.03	0.01	0.02	-	5	0
Iron	**24**	**07/15/88-06/18/97**	**0.01**	**3.3**	**0.2362**	**0.0387**	**-**	**0.3**	**1**
Sulfate	**24**	**07/15/88-06/18/97**	**45**	**1030**	**656.5**	**725.6**	**-**	**250**	**21**
Nitrate	1	07/23/96	0.02	0.02	0.02	-	-	10	0
Orthophosphate	2	05/30/90-09/17/91	0.005	0.007	0.007	0.005	-	-	-
Manganese	**21**	**07/15/88-06/18/97**	**0.005**	**0.11**	**0.0161**	**0.0111**	**-**	**0.05**	**1**
Magnesium	8	07/15/88-06/21/93	29	190	140.8	126.7	-	-	-
Bicarbonate as HCO_3^-	24	07/15/88-06/18/97	200	388	287.8	315.5	-	-	-
Total Alkalinity as $CaCO_3$	24	07/15/88-06/18/97	200	388	294.6	322.5	-	-	-
Total Hardness as $CaCO_3$	24	07/15/88-06/18/97	251	1410	951.9	1074.9	-	-	-

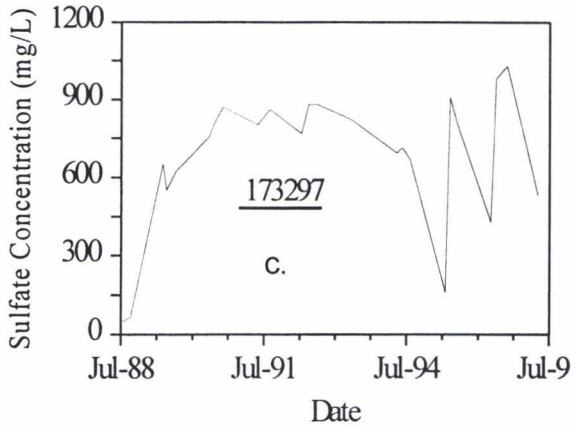


Figure 66. Time-series distributions of flow, TDS, and sulfate at Station 173297.

The next downstream station is located close to the intersection with Right Fork Miller Creek. The summary water flow and quality data at this station, 173295, are given in Table 47. The data indicate that flow varied from 0.001 to 19.8 cfs between 1981 and 1997 with the seasonal means of 1.4, 0.115, and 0.227 cfs for Seasons 1, 2, and 3, respectively. However, the time-series flow data shown in Figure 67a indicate that this peak flow of 19.8 cfs occurred in 1991 only. At all other times, the flow remained relatively small as indicated by the seasonal means. Compared to the flow data given at upstream station 173297, it can be concluded that flow has seasonally increased at this downstream station.

The water quality data suggest that TDS, iron, and sulfate are the major concerns with peak concentrations of 2210, 1, and 1300 mg/L, respectively. The time-series concentration data of TDS and sulfate are shown in Figures 67b and 67c, respectively. The two plots show almost similar behavior between the two parameters with increasing trends from 1980 to 1997. The trend analysis showed that both TDS and sulfate have substantially high increasing seasonal trends with good probability; the trend of TDS was 40.3 mg/L per year and for sulfate, it was 33.5 mg/L per year.

Table 47. Summary water quality data at Stream Station 173295 of North Fork of the Right Fork Miller Creek in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	36	01/27/81-06/18/97	0.001	19.8	1.4	0.1152	0.2267	-	-
pH	**39**	**08/28/80-06/18/97**	**6.8**	**8.9**	**8**	**8.1**	**7.8**	**6.5-8.5**	**3**
TSS	25	08/28/80-06/18/97	2	46	11.9	16.5	4	-	-
TDS	**26**	**08/28/80-06/18/97**	**240**	**2210**	**1183.9**	**1421**	**1096.3**	**500**	**24**
Dissolved Oxygen	6	08/13/88-09/15/89	5.1	8.5	8	6.2	-	-	-
S. Cond. (µmhos/cm)	39	08/28/80-06/18/97	1	2400	1356.8	1595.9	1550	-	-
Chromium	1	10/04/83	0.05	0.05	-	0.05	-	0.05	0
Cadmium	1	10/04/80	0.005	0.005	-	0.005	-	0.01	0
Mercury	1	10/04/83	0.2	0.2	-	0.2	-	0.002	1
Arsenic	1	10/04/83	0.001	0.001	-	0.001	-	0.05	0
Lead	1	10/04/83	0.05	0.05	-	0.05	-	0.05	0
Zinc	2	10/04/83-09/17/91	0.01	0.032	-	0.021	-	5	0
Iron	**26**	**08/28/80-06/18/97**	**0.11**	**1**	**0.2317**	**0.3686**	**0.2033**	**0.3**	**8**
Sulfate	**26**	**08/28/80-06/18/97**	**27**	**1300**	**629.9**	**723.7**	**468**	**250**	**22**
Nitrate	5	08/28/80-10/04/83	0.56	0.92	-	0.8167	0.57	10	0
Manganese	24	08/28/80-06/18/97	0	0.04	0.0183	0.028	0.0173	0.05	0
Magnesium	7	04/28/81-06/21/93	20	161	80	145.5	135	-	-
Calcium	5	04/28/81-01/06/84	60	176	87.1	176	168	-	-
Bicarbonate as HCO_3^-	22	04/28/81-06/18/97	250	375	300.1	330.3	366	-	-
Total Alkalinity as $CaCO_3$	22	04/28/81-06/18/97	204.9	375	287.1	325.2	300	-	-
Total Hardness as $CaCO_3$	17	09/30/88-06/18/97	638	1476	1077.1	1127.5	-	-	-

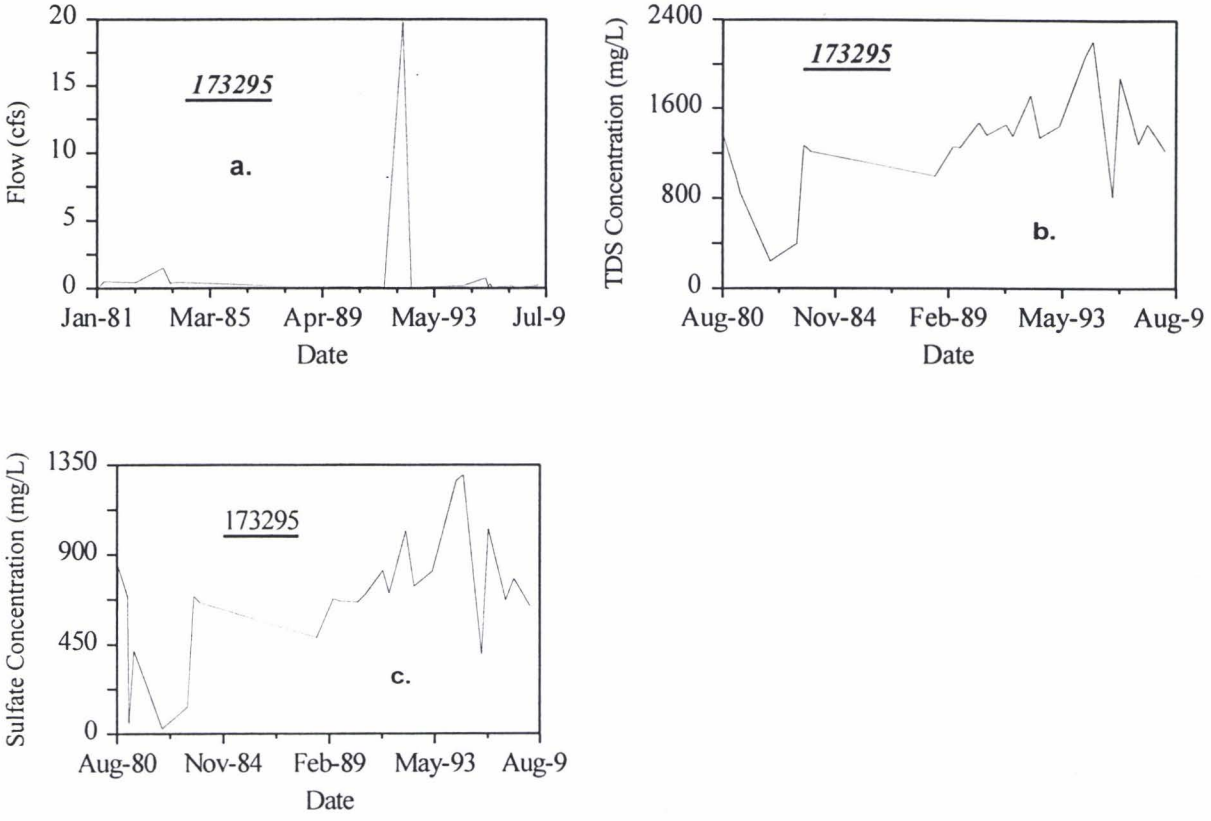


Figure 67. Time-series distributions of flow, TDS, and sulfate at Station 173295.

The data from these two stream stations indicate that flow remained relatively consistent and small along this reach except for a few high flow spikes. The downstream station showed some increased flow indicating no serious water loss. However, the water quality remained poor, especially with respect to TDS, iron, and sulfate, with most parameters showing increasing seasonal trends from 1980 to 1997. Unfortunately, there were no data on heavy metals. The dissolved oxygen concentration remained high at all times indicating good aerobic conditions for fish habitat.

Springs

The first spring discussed here is 173330 which was used in establishing the background concentrations. Therefore, the water quality data of this spring will not be discussed, but the data indicate the concentrations to be much less than the MCLs. The flow data from this spring showed a range of 0 to 0.01 cfs between 1993 and 1997 with 14 data points. The mean flows were 0.0024 and 0.0004 cfs for Seasons 1 and 2, respectively, indicating high flow during spring and summer. The time-series distribution of flow at this spring is shown in Figure 68 where it is seen that the flow peaked in 1994. At other times, the flow was relatively uniform and less than 0.002 cfs.

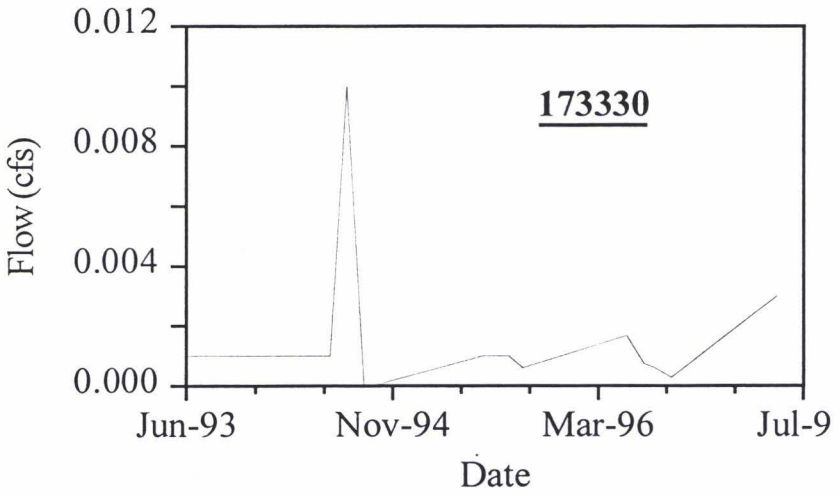


Figure 68. Time-series distribution of flow at Station 173330.

The second spring, 173320, is located near the north fork of Right Fork Miller Creek. This spring is located at 9,480 feet of elevation in the Price River Formation. The summary water flow and quality data given in Table 48 indicate that flow varied between 0 and 0.006 cfs from 1988 to 1997. It should be noted that there are only 22 data points for the entire 11 years indicating limited data availability due to reduced monitoring. The time-series distribution of flow at this spring is shown in Figure 69 where it is seen that flow is almost zero from 1989 to 1996. Due to the erratic nature of flow associated with no flow during parts of the observed period, the trend analysis produced poor results. Although Figure 69

Table 48. Summary water quality data at Spring 173320 in the Price River Watershed obtained from the Star Point Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	22	07/15/88-06/18/97	0	0.006	0.001	0.0008	-	-	-
pH	**7**	**07/15/88-06/18/97**	**7.5**	**8.4**	**7.9**	**7.8**	**-**	**6.5-8.5**	**0**
TDS	5	07/15/88-06/18/97	234	268	252.5	236	-	500	0
S. Cond. (µmhos/cm)	6	07/15/88-06/18/97	280	690	513.8	285	-	-	-
Lead	3	07/15/88-06/06/89	0.02	0.02	0.02	0.02	-	0.05	0
Zinc	3	07/15/88-06/06/89	0.01	0.01	0.01	0.01	-	5	0
Iron	5	07/15/88-06/18/97	0.02	0.27	0.1425	0.05	-	0.3	0
Sulfate	5	07/15/88-06/18/97	2	16	12	2	-	250	0
Manganese	5	07/15/88-06/18/97	0.005	0.01	0.0088	0.01	-	0.05	0
Magnesium	3	07/15/88-06/06/89	17	21	18	21	-	-	-
Bicarbonate as HCO_3^-	5	07/15/88-06/18/97	190	264	224.3	213	-	-	-
Total Alkalinity as $CaCO_3$	5	07/15/88-06/18/97	190	264	224.3	213	-	-	-
Total Hardness as $CaCO_3$	5	07/15/88-06/18/97	218	273	235.5	234	-	-	-

shows no flow during most of the monitoring period, a possible reason for this behavior may be lack of data rather than no flow. The water quality data from this spring are limited, and this data set shows no serious water quality concerns.

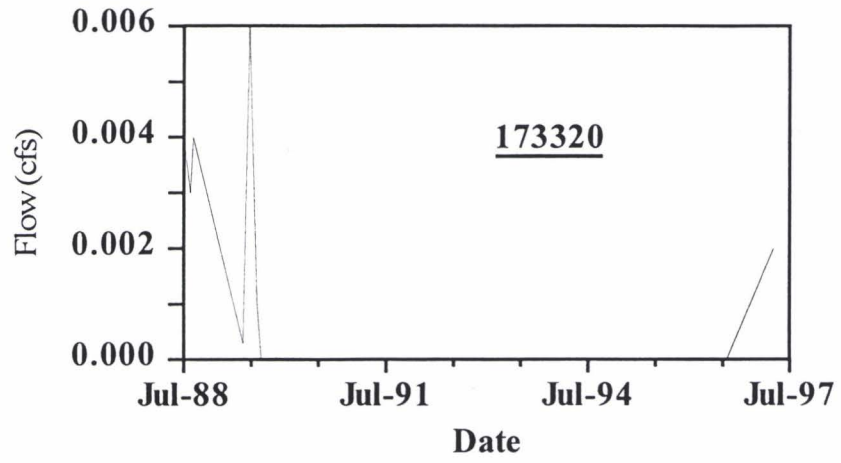


Figure 69. Time-series distribution of flow at Station 173320.

The third spring, 173318, is located at the upstream end of the North Fork at 9480 feet of elevation in the Castlegate Formation. The summary flow and quality data are given in Table 49. The flow data show a variability of 0.002 to 0.01 cfs from 1988 to 1997 with only 25 data points. The means of Seasons 1 and 2 suggest the presence of similar flows of around 0.0035 cfs. The time-series flow data at this spring are shown in Figure 70 which shows consistent flow during the entire period, except in 1991, when the flow was high at around 0.01 cfs. The water quality data are limited with no data on dissolved oxygen and heavy metals. The only chemical of concern was iron, but compared to the background value given in Table 35, it can be concluded that iron may not be a priority concern at this spring.

The fourth spring, 173326, is located between Right and North Forks. This spring is located at 10,060 feet of elevation in the North Horn Formation. The summary flow and quality data are given in Table 50 which shows that flow varied from 0 to 2.5 cfs during 1980 to 1997. The means of Seasons 1 and 2 were 0.157 and 0.0008 cfs, respectively. The time-series

Table 49. Summary water quality data at Spring 173318 in the Price River Watershed obtained from the Star Point Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	25	07/05/88-06/18/97	0.002	0.01	0.0042	0.0036	-	-	-
pH	**28**	**07/05/88-06/18/97**	**6.2**	**8.6**	**7.6**	**7.6**	**-**	**6.5-8.5**	**1**
TDS	22	06/05/89-06/18/97	148	250	209.5	209.4	-	500	0
S. Cond. (µmhos/cm)	28	07/05/88-06/18/97	270	2560	408	561.2	-	-	-
Lead	8	06/05/89-10/01/96	0.02	0.05	0.02	0.0275	-	0.05	0
Zinc	5	06/05/89-09/18/91	0.01	0.02	0.015	0.0133	-	5	0
Iron	**21**	**06/05/89-06/18/97**	**0.01**	**0.46**	**0.0864**	**0.15**	**-**	**0.3**	**2**
Sulfate	22	06/05/89-06/18/97	2	33	13.7	7.6	-	250	0
Nitrate	2	06/05/89-07/11/89	2.4	2.4	2.4	-	-	10	0
Orthophosphate	2	06/05/89-07/1189	0.028	0.032	0.03	-	-	-	-
Manganese	18	06/05/89-06/18/97	0.005	0.02	0.0083	0.01	-	0.05	0
Magnesium	5	09/15/89-06/25/93	10	20	14.5	19.3	-	-	-
Bicarbonate as HCO_3^-	22	06/05/89-06/18/97	130	249	187.6	189.6	-	-	-
Total Alkalinity as $CaCO_3$	22	06/05/89-06/18/97	130	249	188.7	190.7	-	-	-
Total Hardness as $CaCO_3$	22	06/05/89-06/18/97	145	234	204.6	201.4	-	-	-

Table 50. Summary water quality data at Spring 173326 in the Price River Watershed obtained from the Starpoint Mine. All units are in mg/l unless specified and bold lines indicate COC.

Parameter	# Data Points	Time Period	Min.	Max.	Mean (S1)	Mean (S2)	Mean (S3)	MCL	# of Exceed.
Flow (cfs)	31	12/30/80-06/17/97	0	2.5	0.1571	0.0008	0	-	-
pH	**25**	**09/11/79-06/17/97**	**6.4**	**8.3**	**7.7**	**7.6**	**7.2**	**6.5-8.5**	**0**
TSS	3	09/30/80-10/05/83	0.5	26	-	9.2	-	-	-
TDS	23	09/11/79-06/17/97	190	336	238.6	265.7	262	500	0
S. Cond. (µmhos/cm)	25	09/11/79-06/17/97	245	506	408.5	414.8	400	-	-
Chromium	1	10/05/83	0.05	0.05	-	0.05	-	0.05	0
Cadmium	1	10/05/83	0.005	0.005	-	0.005	-	0.01	0
Mercury	1	10/05/83	0.2	0.2	-	0.2	-	0.002	1
Arsenic	1	10/05/83	0.001	0.001	-	0.001	-	0.05	0
Lead	2	10/05/83-09/18/91	0.02	0.05	-	0.035	-	0.05	0
Zinc	2	10/05/83-09/18/91	0.01	0.021	-	0.0155	-	5	0
Iron	**22**	**09/30/80-06/17/97**	**0.01**	**2.3**	**0.148**	**0.4383**	**2.3**	**0.3**	**4**
Sulfate	23	09/11/79-06/17/97	2	46	14.3	15.6	3	250	0
Nitrate	1	10/05/83	0.26	0.26	-	0.26	-	10	0
Manganese	**20**	**09/30/80-06/17/97**	**0.001**	**0.2**	**0.025**	**0.057**	**0.013**	**0.05**	**3**
Magnesium	9	09/11/79-06/24/93	5.3	18.7	8.8	12.3	5.3	-	-
Calcium	7	09/11/79-10/05/83	67.2	85.6	72	78.8	85.6	-	-
Bicarbonate as HCO_3^-	23	09/11/79-06/17/97	166	327	218.3	274.1	327	-	-
Total Alkalinity as $CaCO_3$	19	08/29/81-06/17/97	166	258	217.9	240.5	-	-	-
Total Hardness as $CaCO_3$	16	07/15/88-06/17/97	178	277	229.8	259	-	-	-

distribution of flow at this spring is shown in Figure 71a where it is clearly seen that this peak flow of 2.5 cfs occurred once in 1992. At all other times, the flow was small as indicated by the mean of Season 2. The trend results, given in Table A28 in Appendix A, indicate that flow had a zero trend with good probability. The summary water quality data shown in Table 50 indicate that iron and manganese are the only concerns. The time-series distributions of iron and manganese, shown in Figures 71b and 71c, indicate the presence of a few peak concentrations. In the case of iron, these peaks were visible in 1980 and 1993 whereas manganese showed the presence of two peaks in 1988 and 1991. According to the results given in Table A28 in Appendix A, iron showed a decreasing seasonal trend with good probability.

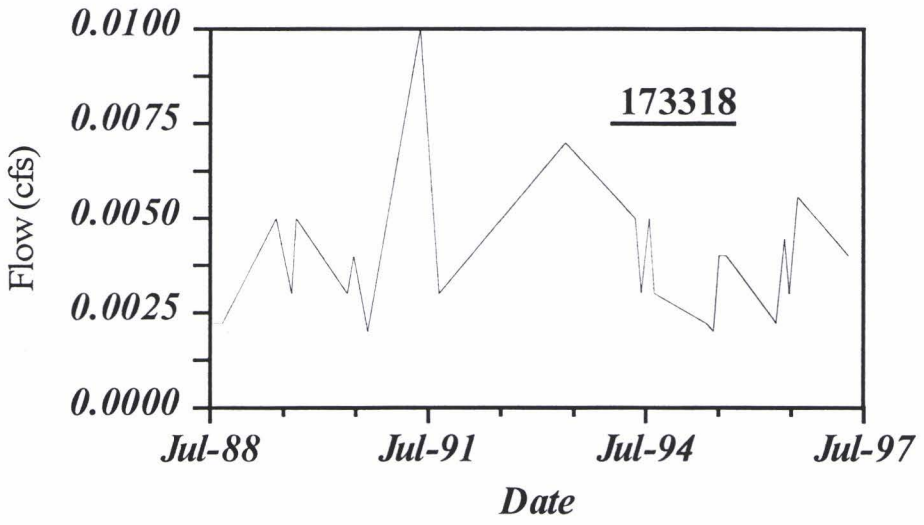


Figure 70. Time-series distribution of flow at Station 173318.

The flow and quality data from these springs indicate the presence of flow during Seasons 1 and 2 with one or more peak flows during the entire period. The data does not suggest drying of springs or reduced flow. However, this conclusion needs to be further confirmed with close monitoring since the currently available flow data are inadequate. There are no serious water quality concerns except for iron and/or manganese. Again, it should be noted that the water quality data are limited and not adequate for a detailed analysis. More data are

needed with respect to all parameters, and data collection on missing parameters such as heavy metals, TSS, and dissolved oxygen should be commenced as soon as possible.

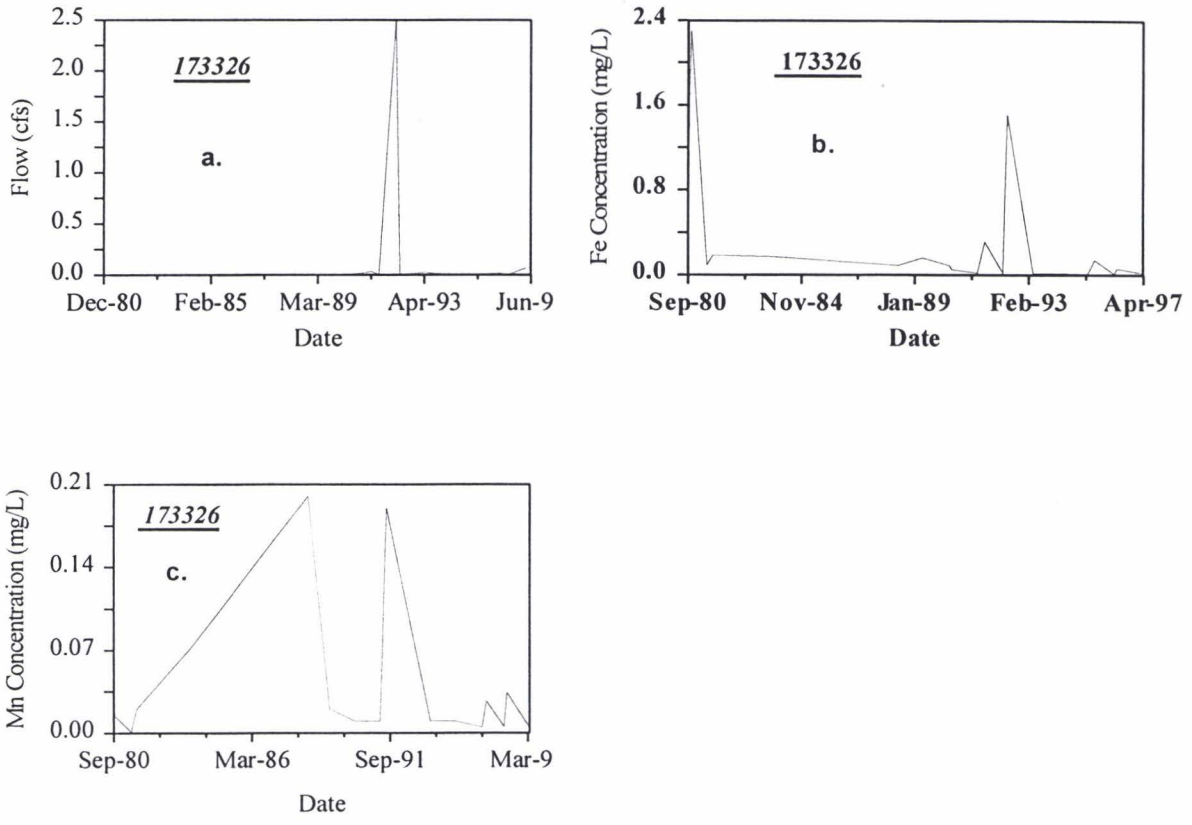


Figure 71. Time-series distributions of flow, iron, and manganese at Station 173326.

5.0 SUMMARY AND CONCLUSIONS

The work carried out in this project focused primarily on the analysis of water flow and quality in the Price River Watershed. There are a number of active coal mines in the Price River Watershed, and the mines included in the analysis were White Oak, Skyline, and Starpoint. The water-related data for the analysis were available from the APPX data base of the State of Utah and the USGS. The data provided information related to flow and concentrations of selected physical, chemical, and biological parameters from streams, springs, mine interceptions, mine discharges, and ground water. Although there are a large number of monitoring stations located within the Price River Watershed and in the areas overlapping with the Huntington Watershed, only a small number of stations contained adequate data for detailed statistical analysis and interpretation. The final analysis included 20 stream, 13 spring, 1 seep, 4 mine discharge, 4 mine interception, and 5 ground water stations. In addition, the precipitation, evapotranspiration, and discharge from Scofield Reservoir to the Price River were analyzed. The statistical analysis included seasonal means, trends, and correlations. The background concentrations of commonly occurring parameters of concern were evaluated for White Oak and Skyline Mines together, and separately for Starpoint Mine. The background concentrations were obtained from selected springs that are located at high elevations and away from coal mining operations. The research approach included a number of tasks such as development of hydrogeological conceptual models of coal mining areas, analysis of flow and quality data for the variability of values over the monitoring period, statistical analysis, time-series distributions, and interpretation.

The major surface water pathways include Mud Creek flowing from south to north in the White Oak and Skyline Mines with associated major tributaries such as Eccles Creek, Finns Canyon, Boardinghouse Canyon, Burnout Creek, Whiskey Canyon, and South Fork. The Skyline Mine area included the Tie Fork area overlapping with the Huntington Watershed, and South and North Forks of Miller Creek.

The conclusions drawn from this study can be summarized as follows:

5.1 Precipitation and Evapotranspiration

The mean monthly precipitation for Seasons 1, 2, and 3, were 1.67, 1.79 , and 2.7, inches, respectively, with a range of 0 to 8.73 inches from 1984 to 1997. The same values for ET were 4.7, 3.7, and 0.99 inches with a range of 0.48 to 6.76 inches. These results indicate that during the spring to early summer months, ET exceeded the precipitation by more than three-fold indicating a net water loss from the watershed. However, during the winter months, ET was almost one-third of the precipitation indicating good recharge to the watershed.

5.2 White Oak and Skyline Mines

Whiskey Canyon

The flow in Whiskey Canyon showed an increasing seasonal trend at the station close to Eccles Creek from 1977 to 1985 and a decreasing trend from 1985 to 1994. The only spring located upstream of Whiskey Canyon showed a negligible trend of flow from 1980 to 1995. In general, flow in the Whiskey Canyon or in the spring did not indicate a long-term loss of water. There were serious water quality problems in Whiskey Canyon with respect to TSS, TDS, iron, and manganese from 1978 to 1995, and the problems became serious towards the downstream locations. The dissolved oxygen concentrations along the stream remained sufficiently high indicating good aerobic conditions and no presence of biodegradable organics. Although the sources responsible for these water quality problems cannot be identified as recharge mechanisms such as base flow or surface runoff have not been quantified or analyzed for water quality. The water quality of springs did not indicate any serious concerns. The ground water monitoring stations had limited data, and these data did not indicate serious water quality concerns. However, more data are needed before any conclusion can be made on ground water quality.

South Fork

Water flow data from two stream stations along the South Fork, which is a tributary to Whiskey Canyon, showed decreasing seasonal trends from 1978 to 1998, especially the

downstream locations. Although flow increased from upstream to downstream locations due to base flow and runoff, the trend results showed a decreasing trend over time at each station. The water quality data from the two stations did not indicate any serious water quality concerns in South Fork. The only spring located in the vicinity of South Fork did not contain adequate flow data to make conclusions related to the behavior of flow. However, water quality data from this spring indicated some serious concerns related to TSS and iron from 1982 to 1995 in comparison to the background values.

Eccles Creek

There are four mine discharge monitoring stations located along Eccles Creek. Two of the locations are discharging to sedimentation ponds; and the other two locations, which are UPDES stations, are discharging directly to Eccles Creek. The flow data from these stations indicated that three discharge stations close to the Skyline Mine boundary maintained high flows and showed increasing trends from the 1980's to 1996. However, the downstream UPDES station close to Mud Creek showed small flows with a strong reducing trend over the same period. Water quality data from the three upstream discharge stations, including the UPDES station, indicated serious water quality concerns related to TDS, iron, manganese, and sulfate, and to some extend TSS and lead. Most parameters also showed increasing seasonal trends with good probability. These data suggest the presence of serious water quality concerns that can eventually affect the quality of water in Eccles Creek.

The stream flow data from 1981 to 1997 from six stations showed that Eccles Creek continued to have high flows before discharging to Mud Creek. The flow generally showed an increasing seasonal trend, and the contribution to flow from mine discharges was less than 10%. Also, the contribution to flow from other tributaries remained relatively small, indicating that much of the flow to Eccles Creek may be due to surface runoff, snowmelt, or base flow through nearby O'Connor Fault. Water quality data showed that Eccles Creek has serious and consistent concerns along the entire stream reach. The common parameters of concern are TSS, TDS, iron, sulfate, and manganese. Also, water quality showed significant deterioration after the mine discharge stations located upstream of the South Fork intersection.

Of the two springs monitored along Eccles Creek, Spring 173435 produced substantially high flows consistently and was relatively active over the entire time period. The other spring, 173431, provided more uniform flow over all seasons, but at a much lower rate than the previous spring. Water quality data from these springs did not indicate serious quality concerns. The seep, 173425, had a flow variability of 0.0015 to 0.08 cfs between 1983 and 1996 with a decreasing seasonal trend. The COC at this seep were TDS, iron, and manganese.

Finns Canyon

The flow data from a single stream station showed that Finns Canyon had flows up to 4.2 cfs from 1980 to 1995 with a decreasing seasonal trend. The water quality at this station did not indicate any serious concerns. The flow at a nearby spring showed a maximum flow of 0.1 cfs from 1980 to 1995 with no significant trend. The water quality was acceptable at this spring.

Boardinghouse Canyon

The flow in Boardinghouse Canyon was substantially higher than that of Finns Canyon indicating a strong contribution to the flow of Mud Creek. The USGS stream station provided limited data over a period of five months in 1984, therefore, these data cannot be used in predicting the long-term behavior. The data from the White Oak Mine showed that flow before the Mud Creek intersection showed a decreasing seasonal trend from 1980 to 1995, indicating concerns to water users as well as to the flow in Mud Creek. A nearby spring showed relatively uninterrupted flow from 1980 to 1995 with no trend. Water quality at the spring and Boardinghouse Canyon showed no serious concerns except slightly elevated iron and manganese concentrations.

Mud Creek

The mine discharge station located close to Mud Creek showed flows up to 0.334 cfs from 1982 to 1996 with a decreasing seasonal trend. The discharge from this station is to nearby sedimentation ponds where the water eventually ends up in Eccles Creek. The mine

discharge did not show serious concerns except for some elevated iron concentrations compared to the background value. Flow in Mud Creek below the Eccles Creek intersection showed a substantial loss of water. However, the station below the Green Canyon intersection showed a gain in flow indicating that flow in Mud Creek between these stations has not been affected from 1977 to 1995. Therefore, it may be possible that discharge to the Scofield Reservoir was not affected during this period. However, the water quality of Mud Creek between these two stations showed serious water quality concerns with respect to TDS, TSS, iron, sulfate, and manganese. Potential reasons for this poor water quality may be the poor water quality of contributing tributaries, especially Eccles Creek, together with base flow and runoff. Due to this reason, the quality of water entering the Scofield Reservoir may be affected too. In any event, rigorous monitoring of Mud Creek should be performed to determine the reasons for the poor water quality and for subsequent management planning. Ground water at a nearby location also showed poor quality, especially in TDS, iron, and sulfate.

Burnout Creek

The flow data of Burnout Creek in the Huntington Watershed showed a maximum flow of 10.7 cfs from 1981 to 1996 with a decreasing seasonal trend of 0.022 cfs per year. The water quality of Burnout Creek, measured close to Electric Lake and Upper Huntington Creek showed no serious concerns except for slightly elevated concentrations of lead, iron, and manganese. The spring located close to this stream station showed flows up to 0.019 cfs from 1981 to 1996 with no trend.

5.3 Starpoint Mine

Tie Fork Canyon Area

The stream station located in Wild Cattle Hollow, which is the western branch of the Tie Fork Canyon, showed a flow range of 0 to 8.4 cfs between 1980 and 1998; and flows at all other times remained relatively small, less than 3 cfs. Water quality data did not indicate serious concerns except for some elevated concentrations of iron and manganese compared to the background values.

The two springs in the Tie Fork Area were located at more than 9,000 feet of elevation and away from coal mining operations. One spring showed a flow variability of 0 to 0.096 cfs between 1992 and 1997, but the data were inadequate to determine the long-term behavior of flow. The other spring had a flow range of 0.01 to 0.19 cfs between 1988 and 1997 with the peak occurring in 1995. The flow at this spring increased during this period. Water quality data did not indicate serious concerns except for elevated iron concentrations.

Of the three ground water monitoring stations located in this area, one station showed iron and manganese as the concerns from 1992 to 1997 with a peak iron concentration around 5.8 mg/L. The second station showed high iron concentrations of around 28.7 mg/L in 1994 with the concentration remaining less than 10 mg/L at other times. The last station showed minimal concerns due to iron. In general, iron may be the only water quality concern from these three ground water wells.

Right Fork Miller Creek Area

The data from four mine interception stations showed that Starpoint Mine received water continuously since 1988, and the flow ranged from 0 to 3.6 cfs. The flow remained almost the same between different seasons indicating that mine intercepted water may be linked to a continuous flow network. Two stations showed decreasing seasonal trends of flow whereas one station showed an increasing trend. The water quality was poor with respect to TDS, iron, sulfate, and manganese with peak TDS and sulfate concentrations around 1640 and 990 mg/L, respectively. Unfortunately, the data from these mine interception stations are limited or sometimes not available, especially related to dissolved oxygen and heavy metals.

The data from these two stream stations indicate that flow remained relatively consistent and small along this reach except for a few peak flow spikes. The upstream station had data from 1988 to 1997 with a peak of 2.2 cfs in 1991 and in 1995. The downstream station had data from 1981 to 1997 with a peak of 19.8 cfs in 1991. The downstream station showed some increased flow, indicating no serious concerns to water users. However, water quality remained poor, especially with respect to TDS, iron, and sulfate, with most parameters

showing increasing seasonal trends from 1980 to 1997. Unfortunately, there were no data on heavy metals. The dissolved oxygen concentration remained high at all times indicating good aerobic conditions.

The flow and quality data from the four springs indicated the presence of flow during Seasons 1 and 2 with one or more peak flows during the entire period. Three springs have peak flows of less than 0.01 cfs between late 1988 or 1993 and 1997. One spring had a flow variability of 0 to 2.5 cfs between 1980 and 1997 with the peak occurring once in 1992. The data does not suggest drying up of the springs or reduced flow. However, this conclusion needs to be further confirmed with more closely spaced monitoring since currently available flow data are inadequate. There are no serious water quality concerns except for iron and/or manganese. Again, it should be noted that water quality data are limited and not adequate for a detailed analysis.

5.4 General Remarks

The data from White Oak and Skylines Mines were adequate for a preliminary analysis. However, flow and water quality data from the Starpoint Mine were inadequate. Also, all monitoring stations in Starpoint Mine contained little to no data on dissolved oxygen and heavy metals. In addition, a few monitoring stations showed unexplainable levels of flow that are not comparable to other stations, and the accuracy of these values need to be further verified through future monitoring. The pH data did not indicate any serious concerns due to wastes from mine-related activities. Although the USGS data base contained a large number of monitoring stations, the number of data points were too small for a detailed analysis and data were monitored over a short period of time. The correlation results were poor at almost all the stations, indicating that there are additional dominant mechanisms controlling the dependence between any two parameters of interest. For example, correlation between spring flow and precipitation is usually poor as there is substantial travel time associated with subsurface water movement from the surface to the local recharge zones.

The major limitations of this study are that the results from a detailed tracer study were not available for a comprehensive evaluation of hydraulic connectivity between different sources and formations, and data from the Starpoint Mine are inadequate and missing. In addition, background concentrations selected for the analysis may be subject to debate as water quality in a large watershed such as the Price River may be continuously changing due to natural mechanisms alone. From a management view point, future monitoring should focus on obtaining continuous and spatially-distributed data on a regular basis with emphasis on missing data such as dissolved oxygen and heavy metals. Water data collection programs should be coordinated with all interested parties such as the mining companies, US Forest Service, US Geological Survey, Utah Department of Natural Resources, and Water Conservancy Districts such that resources are allocated efficiently and effectively to obtain continuous, uninterrupted, and spatially-distributed data of all parameters of concern. Any future studies should focus on detailed tracer studies, water balance analysis over a selected number of years, surface water quality modeling for future management of land, and quantification of recharge components to streams and springs through base flow and/or surface runoff. The last item is of great importance as previous studies have speculated that major portions of recharges to Eccles and Mud Creeks are from base flow channeled through fault-associated flow networks. If this is true, then the water flow and quality of these streams are controlled by subsurface processes.

6.0 RECOMMENDATIONS

1. Water quantity and quality monitoring plans should be re-evaluated to improve the monitoring procedures. Through such a re-evaluation, more representative locations of the watershed should be identified and monitored at regular time periods. This re-evaluation should be conducted in close cooperation with all federal, state, coal mining, and local agencies such that better communication can be established. Also, existing data bases should be updated to remove stations with no data, and each valid station should be identified with a storet number, a small description, accurate coordinates, and surface elevation.
2. Monitoring should be performed quarterly, and the number of parameters can be reduced for cost effectiveness. As indicated by this study, the major concerns and/or missing data are with respect to total dissolved and suspended solids, iron, sulfate, manganese, and to a lesser extent lead. Therefore, monitoring should be restricted to a selected number of chemicals such as all heavy metals, dissolved oxygen, pH, TDS, TSS, organics, sulfate, iron, nitrate, total alkalinity, biochemical oxygen demand, and chemical oxygen demand. All recorded data from different stations should follow US EPA accepted quality assurance and quality control protocols.
3. In order to better understand the hydrogeology with respect to hydraulic connectivity between recharge zones to springs and mine interceptions, detailed tracer studies should be conducted at selected mine permit areas. The data from these detailed studies will definitely provide stronger evidence to indicate the direct impact of mining or any other land use on the water movement and corresponding contaminant transport. For future data collection, the major missing data gaps are information related to regional ground water flow, limited ground water sampling locations with adequate data, limited downstream surface water monitoring locations with detailed chemical characteristics, and tracer study data to link monitoring data to assess major transportation mechanisms.
4. Additional ground water monitoring wells should be constructed at representative locations to monitor water flow and quality. The data from ground water monitoring should be used to establish the ground water hydrology in the area and the direction and gradient of the regional water table.

5. The monitoring program carried out by the Starpoint Mine needs to be improved, and further quality control and quality assurance need to be implemented. The data collection should be continuous and all previously discussed parameters should be included in the data base. In addition, new monitoring stations may be needed at representative locations to ensure that monitoring stations are spatially-uniform for better data interpretation.
6. The analysis of water data becomes complex when mine interception and mine discharge data are not properly monitored and accounted. Therefore, mine companies should be provided with better instructions and guidelines on accounting for actual mine interceptions at regular intervals such that a good comparison between interception and discharge can be made. In cases where outside water is used in mining activities, these values should be reported in the data bases as separate parameters.
7. The monitored data should be regularly assessed to determine the prevailing water quantity and quality issues, and regulatory attention should be focused as soon as possible when concerns are observed.
8. Important future studies in this watershed are detailed tracer studies, water balance analysis over a selected number of years, surface water quality modeling for future management of land, and quantification of recharge components to streams and springs through base flow and/or surface runoff.
9. An improved central data base should be maintained to include all water data, and quality control should be maintained when data are entered manually into the data base. The most effective and long-term solution for data analysis is to link the data base to a comprehensive Geographic Information System (GIS). The GIS should be developed in such a manner that immediate concerns related to water issues could be automatically detected and conveyed to the user at regular intervals. The different agencies collecting water-related data should be encouraged to use the GIS to store the data and be given less encouragement to report the data in various reports.

7.0 REFERENCES

Crandall Canyon Mine Permit Documentation, 1996. Utah Division of Oil, Gas, and Mining. Utah Department of Natural Resources, Salt Lake City, UT.

Danielson, T. W., M. D. ReMillard, and R. H. Fuller, 1981. Hydrology of the coal-resource areas in the upper drainages of Huntington and Cottonwood Creeks, Central Utah. U. S. Geological Survey, Water Resources Investigations, Open-File Report 81-539.

Danielson, T. W. and D. A. Sylla, 1983. Hydrology of coal-resource areas in the southern Wasatch Plateau, Utah. U.S. Geological Survey, Water Resources Investigations Report 82-4009.

Evangelou, V. P., L. D. Whittig, and K. K. Tanji, 1984. Dissolved mineral salts derived from Mancos Shale. J. Environ. Qual. 13(1):146-150.

Farnsworth, R. K., E. S. Thompson, and E. L. Peck, 1982. Evaporation Atlas for the Contiguous 48 United States: National Oceanic and Atmospheric Administration Technical Report NWS 33, 27 p.

Fenneman, N. M., 1946. Physical divisions of the United States. U.S. Geological Survey Map, scale 1:7,000,000.

Gilbert, R. O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, NY.

Kaluarachchi, J. J. and A. Abdin, 1998a. Assessment of water quantity and quality in mining areas of Manti-La Sal National Forest: Cottonwood and Huntington Watersheds, Document Part I: Cottonwood Watershed. Utah State University, Logan, UT.

Kaluarachchi, J. J. and A. Abdin, 1998b. Assessment of water quantity and quality in mining areas of Manti-La Sal National Forest: Cottonwood and Huntington Watersheds, Document Part II: Huntington Watershed. Utah State University, Logan, UT.

Kendall, M. G., 1975. Rank Correlation Methods, 4th ed. Charles Griffin, London.

Lindskov, K. L., 1986. Potential effects of anticipated coal mining on salinity of the Price, San Rafael, and Green Rivers, Utah. U. S. Geological Survey, Water Resources Investigations Report 86-4019.

Lines, G. C. and G. G. Plantz, 1981. Hydrologic monitoring in the coal fields of central Utah, August 1978 – September 1979. U.S. Geological Survey Water Resources Investigations Report 81-138, 56 p.

Mundroff, J. C., 1972. Reconnaissance of chemical quality of surface water and fluvial sediment in the Price River basin, Utah. Utah Department of Natural Resources Technical Publication 39, 55 p.

Skyline Mine Permit Documentation, 1979. Utah Division of Oil, Gas, and Mining, Utah Department of Natural Resources, Salt Lake City, UT.

Starpoint Mine Permit Documentation, 1992. Utah Division of Oil, Gas, and Mining, Utah Department of Natural Resources, Salt Lake City, UT.

U.S. Weather Bureau, 1963. Normal annual precipitation (1931-60) for the State of Utah: Map of Utah, scale 1:500,000.

Vaughn Hansen Associates, 1985. Hydrologic inventory and baseline study of the Valley Camp Lease area and adjacent areas, Carbon and Emery Counties, Utah. Salt Lake City, UT.

White Oak Mine Permit Documentation, 1984. Utah Division of Oil, Gas, and Mining, Utah Department of Natural Resources, Salt Lake City, UT.

White Oak Mine Permit Documentation, 1995. Cumulative hydrologic impact assessment (CHIA): Mud Creek Basin and Upper Huntington Creek Basin. Utah Division of Oil, Gas, and Mining, Utah Department of Natural Resources, Salt Lake City, UT.

Williams, J. S., 1975. The natural salinity of the Colorado River. Occasional Paper 7, Utah Water Research Laboratory, Utah State University, Logan, UT.

APPENDIX A - Trend and Correlation Tables

Table A1. Seasonal trend and correlation results at Stream Station 173476.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	68	03/17/77-10/18/95	0	0-0.1212	42	-
TSS	47	06/14/78-10/18/95	-2.3	36.4-1197.5	99.8	-
TDS	48	06/14/78-10/18/95	-0.921	115-237.6	57.1	-
Iron	34	06/14/78-10/18/95	-0.019	0.85-2.4	77.8	-
Manganese	34	06/14/78-10/18/95	-0.001	0.0213-0.5745	87.6	-
Correlations						
TSS vs. Flow						0.06
TDS vs. Flow						0.30
Flow vs. Precipitation						0.22
Flow vs. Evapotranspiration						0.09

Table A2. Seasonal trend and correlation results at Stream Station 173477.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	72	03/17/77-10/18/95	-0.04	0-0.6542	100	-
TSS	58	08/25/77-10/18/95	-5.7	630.3-1952.5	99.7	-
TDS	58	08/25/77-10/18/95	14.8	367.2-495.1	100	-
Iron	42	08/25/77-10/18/95	-0.028	1.7-44.2	72.4	-
Manganese	43	08/25/77-10/18/95	-0.001	0.282-0.89	58.4	-
Correlations						
TSS vs. Flow						0.06
TDS vs. Flow						0.05
Flow vs. Precipitation						0.08
Flow vs. Evapotranspiration						0.01

Table A3. Seasonal trend and correlation results at Spring 173483.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	42	06/26/80-10/18/95	0	0.003-0.0292	97.2	-
Lead	16	08/26/80-10/18/95	0	0.0117-0.0174	98.2	-
Iron	18	06/26/80-10/18/95	0.019	0.6373-1.3	76.4	-
Manganese	31	06/26/80-10/18/95	0	0.0298-0.031	13.8	-
Correlations						
Flow vs. Precipitation						0.02
Flow vs. Evapotranspiration						0.08

Table A4. Seasonal trend and correlation results at Stream Station 173414.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	55	07/30/81-06/24/97	-0.03	0.2049-1.1	100	-
TDS	54	06/30/82-06/23/97	0.519	261-380	7	-
Lead	14	08/20/82-09/24/96	0	0.0176	99.2	-
Iron	55	06/30/82-06/24/97	-0.004	0.06-0.1604	89.6	-
Manganese	56	06/30/82-06/24/97	0	0.01-0.0314	38.6	-
Correlations						
TDS vs. Flow						0.39
Flow vs. Precipitation						0.11
Flow vs. Evapotranspiration						0.40

Table A5. Seasonal trend and correlation results at Stream Station 173478.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	76	06/14/78-10/18/95	-0.057	0.1599-1.9	100	-
TDS	77	06/14/78-10/18/95	7.2	268.6-317.1	100	-
Iron	57	06/14/78-10/18/95	0.003	0.2769-0.431	39	-
Sulfate	76	06/14/78-10/18/95	3.5	38.4-68.8	100	
Manganese	58	06/14/78-10/18/95	0.001	0.0316-0.0536	93.7	-
Correlations						
TDS vs. Flow						0.40
Flow vs. Precipitation						0.06
Flow vs. Evapotranspiration						0.10

Table A6. Seasonal trend and correlation results at Spring 173438.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	11	09/03/91-09/12/96	0	0-0.0003	46	-
TSS	26	06/29/82-07/24/95	-22.9	130.3-476	99.8	-
Iron	26	06/29/82-07/24/95	-0.163	4.4-20.2	99.6	-
Manganese	26	06/29/82-07/24/95	-0.006	0.0502-0.0723	96.9	-
Correlations						
Flow vs. Precipitation						0.07
Flow vs. Evapotranspiration						0.51

Table A7. Seasonal trend and correlation results at Mine Discharge Station 173438.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	23	06/23/89-10/30/96	-0.011	0.1977-0.4099	42.4	-
TSS	30	01/25/89-06/24/97	-1	116-830	7.8	-
TDS	61	01/25/89-10/30/96	47.8	1019-1259.9	87.2	-
Iron	26	01/25/89-06/24/97	-0.1	0.85-3	55.2	-
Sulfate	61	01/25/89-09/25/96	8.3	500.8-577.7	25.9	-
Manganese	25	01/25/89-06/24/97	0.003	0.0576-0.1011	79.9	-
Correlations						
TSS vs. Flow						0.06
TDS vs. Flow						0.21
Flow vs. Precipitation						0.45

Table A8. Seasonal trend and correlation results at Mine Discharge Station 173424.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	81	12/20/83-10/30/96	0.034	0.4906-0.6201	99.6	-
TSS	105	11/30/83-10/30/96	-2	30.9-208.1	98.7	-
TDS	140	11/30/83-10/30/96	87.3	775.9-814.5	100	-
Iron	97	11/30/83-10/30/96	0.015	0.7227-1.7	70.3	-
Sulfate	126	11/30/83-09/25/96	45.5	355.3-374	100	-
Manganese	81	11/30/83-10/30/96	0	0.0478-0.0759	80.5	-
Correlations						
TSS vs. Flow						0.23
TDS vs. Flow						0.20
Flow vs. Precipitation						0.16

Table A9. Seasonal trend and correlation results at UPDES Discharge Station 173448.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	248	10/01/82-12/21/93	0.089	0.8236-0.8678	100	-
TDS	335	10/01/82-07/27/94	82.6	742-854.6	100	-
Iron	284	10/01/82-12/28/93	0.026	0.3449-0.4759	100	-
Sulfate	115	10/01/82-07/27/94	50	408.3-428.7	100	-
Manganese	23	10/01/82-02/11/92	0.02	0.0571-0.0695	99.2	-
Correlations						
TDS vs. Flow						0.39
Flow vs. Precipitation						0.08

Table A10. Seasonal trend and correlation results at Seep 173425.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	66	11/10/83-10/30/96	-0.003	0.0142-0.0299	100	-
TDS	68	11/10/83-10/30/96	25.5	468.9-540.6	100	-
Lead	12	08/24/84-09/25/96	0.001	0.0203	99	-
Iron	67	11/10/83-10/30/96	0.001	0.1487-0.2312	20.2	-
Manganese	67	11/10/83-10/30/96	0	0.0299-0.08	31.8	-
Correlations						
TDS vs. Flow						0.38
Flow vs. Precipitation						0.04

Table A11. Seasonal trend and correlation results at Stream Station 173417.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	65	07/29/81-06/24/97	-0.003	0.0238-0.7093	94.2	-
Lead	15	11/11/81-09/16/96	0	0.001-0.0291	86.2	-
Iron	69	07/29/81-06/24/97	-0.008	0.2167-0.6719	94.7	-
Manganese	69	07/29/81-06/24/97	0	0.0175-0.0363	94.5	-
Correlations						
Flow vs. Precipitation						0.21
Flow vs. Evapotranspiration						0.17

Table A12. Seasonal trend and correlation results at Stream Station 173415.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	61	08/19/82-06/24/97	0.096	1-3.5	99	-
TSS	88	07/29/81-06/24/97	-0.667	19.2-149.9	78.6	-
TDS	88	07/29/81-06/24/97	41.7	405.5-548.2	100	-
Lead	15	11/11/81-09/25/96	0	0.003-0.3078	98.4	-
Iron	88	07/29/81-06/24/97	-0.019	0.5295-2.2	83.4	-
Sulfate	87	07/29/81-09/25/96	25	96.9-129.5	100	-
Manganese	88	07/29/81-06/24/97	-0.001	0.1203-0.2479	44.4	-
Correlations						
TSS vs. Flow						0.14
TDS vs. Flow						0.12
Flow vs. Precipitation						0.28
Flow vs. Evapotranspiration						0.08

Table A13. Seasonal trend and correlation results at Stream Station 173428.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	73	06/30/82-10/30/96	0.123	0.8467-4.7	99.9	-
TSS	106	07/29/81-10/30/96	-0.5	27.6-209	41.8	-
TDS	105	07/29/81-10/30/96	53	401.2-586.4	100	-
Iron	105	07/29/81-10/30/96	-0.014	0.4541-2.6	78.5	-
Sulfate	103	07/29/81-09/26/96	35.1	135.5-228.9	100	-
Manganese	105	07/29/81-10/30/96	-0.004	0.1385-0.168	95.4	-
Correlations						
TSS vs. Flow						0.68
TDS vs. Flow						0.09
Flow vs. Precipitation						0.19
Flow vs. Evapotranspiration						0.16

Table A14. Seasonal trend and correlation results at Stream Station 173418.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	67	11/11/81-06/24/97	-0.022	2.7-11	35.1	-
TSS	103	07/29/81-06/24/97	-1.5	31.8-226.2	98.6	-
TDS	103	07/29/81-06/24/97	26.3	403.6-493.2	100	-
Iron	102	07/29/81-06/24/97	-0.052	0.6927-2.6	100	-
Sulfate	100	07/29/81-09/25/96	17.2	88-156.4	100	-
Manganese	102	07/29/81-06/24/97	-0.006	0.0946-0.1433	100	-
Correlations						
TSS vs. Flow						0.54
TDS vs. Flow						0.30
Flow vs. Precipitation						0.17
Flow vs. Evapotranspiration						0.11

Table A15. Seasonal trend and correlation results at Stream Station 173452.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	19	11/19/87-10/30/96	0.35	2.8-7	93.7	-
TSS	110	07/29/81-10/30/96	-1.2	34.9-263.9	91	-
TDS	110	07/29/81-10/30/96	28	436.5-493.4	100	-
Iron	109	07/29/81-10/30/96	-0.041	0.567-3.1	100	-
Sulfate	107	07/29/81-09/25/96	16.5	101.8-151.9	100	-
Manganese	109	07/29/81-10/30/96	-0.005	0.078-0.1253	100	-
Correlations						
TSS vs. Flow						0.47
TDS vs. Flow						0.31
Flow vs. Precipitation						0.51
Flow vs. Evapotranspiration						0.49

Table A16. Seasonal trend and correlation results at Spring 173431.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	63	10/23/81-09/24/96	0	0.0016-0.0036	48.1	-
TDS	41	11/12/81-09/24/96	-1.3	326.5-455	87.1	-
Lead	14	11/12/81-09/24/96	0	0.001-0.0168	65.2	-
Iron	42	11/12/81-09/24/96	-0.004	0.1148-0.1221	84.9	-
Manganese	42	11/12/81-09/24/96	0.001	0.0087-0.0269	99.1	-
Correlations						
TDS vs. Flow						0.35
Flow vs. Precipitation						0.15
Flow vs. Evapotranspiration						0.29

Table A17. Seasonal trend and correlation results at Spring 173435.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	98	19/30/80-06/23/97	0.003	0.21-0.235	94	-
TDS	55	09/11/79-06/23/97	0.4	334.3-385.4	49.2	-
Lead	14	11/11/81-09/25/96	0	0.001-0.0168	98.9	-
Iron	54	09/30/80-06/23/97	0.015	0.6164-0.6827	99.4	-
Manganese	54	09/30/80-06/23/97	0.004	0.0363-0.0515	100	-
Correlations						
TDS vs. Flow						0.01
Flow vs. Precipitation						0.05
Flow vs. Evapotranspiration						0.10

Table A18. Seasonal trend and correlation results at Stream Station 173480.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	53	02/25/80-10/18/95	-0.012	0-0.7711	99.4	-
Cadmium	11	08/25/80-05/19/94	0	0.0055-0.011	54.2	-
Lead	11	08/25/80-05/19/94	0.001	0.0055-0.023	94.1	-
Iron	28	06/25/80-07/13/95	-0.006	0.7132-2.1	11.2	-
Manganese	28	06/25/80-07/13/95	0.001	0.0312-0.0438	67.9	-
Correlations						
Flow vs. Precipitation						0.26
Flow vs. Evapotranspiration						0.02

Table A19. Seasonal trend and correlation results at Spring 173484.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	35	06/25/80-10/18/95	0	0.0088-0.0157	78.9	-
Lead	14	08/27/80-10/18/95	0	0.012-0.0249	92.2	-
Iron	17	06/25/80-10/18/95	-0.001	0.0753-0.1089	57.6	-
Correlations						
Flow vs. Precipitation						0.47
Flow vs. Evapotranspiration						0.16

Table A20. Seasonal trend and correlation results at Stream Station 173479.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	52	06/25/80-10/18/95	-0.115	0.7098-2.3	99.9	-
Iron	37	06/25/80-10/18/95	-0.026	0.025-0.5507	98.7	-
Manganese	37	06/25/80-10/18/95	0.002	0.009-0.0292	99.4	-
Correlations						
Flow vs. Precipitation						0.19
Flow vs. Evapotranspiration						0.02

Table A21. Seasonal trend and correlation results at Spring 173486.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	44	08/27/80-10/18/95	0	0.0143-0.0282	69.9	-
Lead	17	08/27/80-10/18/95	0.001	0.0123-0.017	96.9	-
Iron	22	08/27/80-10/18/95	0.028	0.3571-0.443	98.9	-
Manganese	33	08/27/80-10/18/95	0.001	0.0202-0.04	99.2	-
Correlations						
Flow vs. Precipitation						0.29
Flow vs. Evapotranspiration						0.01

Table A22. Seasonal trend and correlation results at UPDES Discharge Station 173449.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	52	09/30/82-06/00/96	-0.001	0.0153-0.0298	100	-
TDS	28	09/30/82-08/23/87	10	272.2-384.5	17.1	-
Iron	27	09/30/82-08/23/87	0.25	0.585-0.8788	0.84	-
Correlations						
TDS vs. Flow						0.16
Flow vs. Precipitation						0.04
Flow vs. Evapotranspiration						0.15

Table A23. Seasonal trend and correlation results at Stream Station 173475.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	70	03/17/77-10/18/95	-0.283	5.3-12.5	95	-
TSS	80	03/17/77-10/18/95	-1.2	38.4-668	80.8	-
TDS	81	03/17/77-10/18/95	15.2	368.5-391.8	100	-
Iron	63	03/17/77-10/18/95	-0.008	0.7828-3.9	31.5	-
Manganese	63	03/17/77-10/18/95	0.001	0.0822-0.3578	55.8	-
Correlations						
TSS vs. Flow						0.58
TDS vs. Flow						0.49
Flow vs. Precipitation						0.24
Flow vs. Evapotranspiration						0.02

Table A24. Seasonal trend and correlation results at Stream Station 173474.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	107	03/17/77-10/18/95	0.34	3.4-10.4	99	-
TSS	100	03/17/77-10/18/95	0.357	63.3-232.8	59	-
TDS	102	03/17/77-10/18/95	11.6	360.3-387.9	100	-
Iron	84	03/17/77-10/18/95	0.014	0.7036-11.8	92.3	-
Sulfate	82	03/17/77-10/18/95	7	70.5-100	100	-
Manganese	77	03/17/77-10/18/95	0.002	0.0917-0.1329	96.2	-
Correlations						
TSS vs. Flow						0.38
TDS vs. Flow						0.22
Flow vs. Precipitation						0.17
Flow vs. Evapotranspiration						0.02

Table A25. Seasonal trend and correlation results at Stream Station 173419.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	51	07/30/81-09/11/96	-0.022	0.2799-2.8	93.4	-
Lead	15	11/10/81-09/11/96	0.001	0.001-0.0162	99.3	-
Iron	31	07/30/81-09/11/96	-0.003	0.1592-0.28	46.5	-
Manganese	31	07/30/81-09/11/96	0.001	0.015-0.0393	96.5	-
Correlations						
Flow vs. Precipitation						0.42
Flow vs. Evapotranspiration						0.35

Table A26. Seasonal trend and correlation results at Mine Interception Station 173353.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	16	07/27/88-02/27/95	0	0.0017-0.0043	76.8	-
TDS	16	07/27/88-07/20/94	31	891.2-985	93.6	-
Iron	16	07/27/88-07/20/94	0.575	1.1-1.8	99.2	-
Sulfate	16	07/27/88-07/20/94	24	521.8-582.5	98.3	-
Correlations						
TDS vs. Flow						0.07
Flow vs. Precipitation						0.41

Table A27. Seasonal trend and correlation results at Mine Interception Station 173354.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	59	10/31/92-07/31/97	-0.001	0.0029-0.0032	100	-
TDS	18	10/32/92-06/12/97	49.8	475.5-548	99.9	-
Iron	18	10/31/92-06/12/97	0.12	0.275-1.3	95.6	-
Sulfate	18	10/31/92-06/12/97	26.5	124.5-166.2	99.7	-
Manganese	18	10/31/92-06/12/97	0.014	0.0292-0.0512	96.5	-
Correlations						
TDS vs. Flow						0.48
Flow vs. Precipitation						0.15

Table A28. Seasonal trend and correlation results at Spring 173326.

Parameter	# Data Points	Time Period	Seasonal Trend Slope (cfs or mg/L per year)	Range of Seasonal Means	Probability of Trend Slope (%)	Correlation Coefficient
Trends						
Flow	31	12/30/80-06/17/97	0	0-0.1571	95.3	-
Iron	22	09/30/80-06/17/97	-0.005	0.148-2.3	98	-
Manganese	20	09/30/80-06/17/97	0	0.013-0.057	53.6	-
Correlations						
Flow vs. Precipitation						0.30
Flow vs. Evapotranspiration						0.07